Bacteria TMDLs for Sepulcher Creek, Toms Creek and Crab Orchard Branch Wise County, Virginia

Submitted by

Virginia Department of Environmental Quality

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Executive Summary

This report presents the development of a Bacteria Total Maximum Daily Load (TMDL) for the Sepulcher Creek, Toms Creek and Crab Orchard Branch watersheds. These watersheds are located in Wise County and are tributaries to Guest River which is a tributary to Clinch River, part of the Tennessee River Basin (USGS Hydrologic Unit Code (06010205). The waterbody identification code (WBID, Virginia Hydrologic Unit) for Sepulcher Creek, Toms Creek and Crab Orchard Branch is VAS-P11R in the Southwest region of Virginia.

The impairment on Sepulcher Creek is 2.6 miles long, on Toms Creek is 11.6 miles long and Crab Orchard is 2.4 miles in length. Each impaired segment includes its entire length from headwaters extending downstream to confluence with Guest River.

The drainage area of Sepulcher Creek watershed is approximately 8.8 square miles, Toms Creek is 16 square miles and Crab Orchard Branch is 2.7 square miles. The average annual rainfall as recorded at Wise, VA is 46.9 inches. Since the late 1800s Wise County has been mined for its coal resources and the forests logged. Although there are few active mines in the three watersheds today, the landscape includes active mining, abandoned mine lands and reclaimed mine lands. The predominant land use today is forest, with mining landuses the second predominant use followed by residential, commercial, pasture and transportation. The watershed study area for Sepulcher Creek is approximately 5,620 acres, Toms Creek is 10,551.3 acres and Crab Orchard Branch is 1,715 acres. Maps of the distribution of land use in the watersheds indicates that the pasture land and residences tend to be located closer to the stream, while the forest land is farther from the stream. This is most likely due to the hilly topography of the watershed. The steeper slopes at the edges of the watershed have remained forested while the shallower slopes near the stream are developed.

In 1998, Guest River and tributaries Sepulcher Creek, Yellow Creek, Bear Creek, Toms Creek, Little Toms Creek and Crab Orchard Branch were listed as impaired on Virginia's 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 1998) due to violations of the State's water quality standard for fecal coliform bacteria. In 2002, Guest River mainstem, Yellow Creek and Bear Creek were delisted based on data showing they met the swimmable use. The remaining tributaries to Guest River, Sepulcher Creek, Toms Creek, Little Toms Creek and Crab Orchard Branch continued to show violations of the water quality standard and were included on the 2002 303(d) Report on Impaired Waters (VADEQ, 2002). Since Little Toms Creek is a tributary to Toms Creek, this TMDL study is inclusive of both streams when it refers to Toms Creek watershed. Based on 11 samples collected in 1996 at 6BSEP000.55, the Sepulcher Creek geometric mean result was 157 and 457 cfu/100 mL for fecal coliform. The geometric mean criteria was 200 cfu/100 mL for Virginia. During the same summer sampling events, Toms Creek at station 6BRMS000.60 had geometric means of 2,970.2 for 5 samples and 2,448.1 cfu/100 mL for 5 samples, Little Toms Creek at station 6BLTF000.68 had a geometric mean for 5 samples of 1,949.6 cfu/100 mL and Crab Orchard Branch at station 6BCRA000.31 had geometric means of 985.2 for 6 samples and 577.9 cfu/100 mLfor 5 samples. During the most recent 2002 assessment period, Toms Creek and Crab Orchard Branch stations continued to violate the geometric mean criteria. Sepulcher Creek at station 6BSEP000.55 showed improvement with no violations of 42 samples, however a new station upstream showed geometric mean values of 211.9, 364.4 and 151.0 cfu/ 100 mL. Between 2000 and 2001, 27 samples from Little Toms Creek did not violate the geometric mean.

According to Virginia Water Quality Standards (9 VAC 25-260-10A), "all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."

As indicated above, Sepulcher Creek, Toms Creek and Crab Orchard Branch must support all designated uses and meet all applicable criteria. These watersheds do not currently support primary contact recreation.

The load-duration approach is used to develop the TMDL for these watersheds.

The assessment of bacterial sources involves estimating loads from various sources in the watershed. It was accomplished by determining the relative contribution by these sources using Biological Source Tracking (BST) methodology. A total of 12 ambient water quality samples were collected on a monthly basis from September 2002 through October 2003 for BST analysis. The results indicate that the majority of bacteria are coming from anthropogenic sources. Four categories of sources were considered: human, pet, livestock and wildlife. The analyses determined the relative contribution of all bacteria by these sources. The data indicated that on an average basis, relative contributions of bacteria for Sepulcher Creek are – 15% by human, 24% by pet, 31% by livestock, and 30% by wildlife. BST data for Toms Creek are - 17% human, 17% pet, 37% livestock and 30% wildlife. Little Toms Creek was sampled 10 times and the relative contribution by sources are - 15% human, 18% pet, 34% livestock and 33% wildlife. Finally Crab Orchard Creek BST results are - 27% human, 21% pet, 18% livestock and 34% wildlife. Fecal and *E.coli* bacteria were also enumerated as part of the BST analyses.

The bacteria loads in the study watersheds were calculated for point source and non-point sources. The study area has 23 residential sewage treatment plant discharges qualifying for general permits with less that 1000 gallons per day discharge each. Toms Creek watershed has a water treatment plant discharge permit with a permitted flow of 2500 gallons per day. The permitted loads were calculated by multiplying the permitted discharge concentrations (126 cfu/100 ml) times the permitted flow times the appropriate unit conversions. For non-point sources (human, pets, livestock, and wildlife) total annual fecal productions were calculated separately. Data on population density and waste production by septic systems, pets, livestock and wildlife were collected from various sources, and total fecal productions were calculated with appropriate unit conversions.

The load-duration method essentially uses an entire stream flow record to provide insight into the flow conditions under which exceedances of the water quality standard occur. The flow-duration curve uses historical flow data collected at the USGS gaging station (#3524000) as a reference to the small watershed flows. Flow measurements at the sampling stations on each impaired stream were made in 2002 and early 2003. The sampling stations on each stream were also the sites for bacteria water quality sampling collected monthly. The load-duration curve was then developed by multiplying each flow level along the flow-duration curve by the applicable water quality standard and required unit conversions. Each water quality observation is then assigned to a flow interval by comparing the date of each water quality observation to the flow record of the reference stream. The stream flow from the date of the water quality observation is then used to calculate a stream flow and flow-duration interval for the stream. The loads on the load-duration curve are multiplied by 365 days/year to determine the annual loads. The observed loads were plotted on the load-duration curve to determine the number and pattern of exceedances of water quality standards (TMDL).

The results indicated that the highest exceedance of the water quality standard occurred within the normal flow regimes in each watershed. This represents the flow condition under which the largest bacteria reduction is required in order to meet water quality standards. The loads at this flow condition are 1.15×10^{13} cfu/yr for Sepulcher Creek, 1.38×10^{14} cfu/yr for Toms Creek and 2.26×10^{14} cfu/yr in Crab Orchard Branch. To meet water quality standard of instantaneous *E. coli* of 235 cfu/100mL, these loads would have to be reduced by 71%, 84% and 94% to allowable loads of 3.30×10^{12}, 2.57×10^{13} and 1.29×10^{13} cfu/yr respectively. The allowable loads are simply the *E. coli* standard multiplied by the applicable flow condition and the proper unit conversions.

For the watersheds, the average annual *E. coli* load is 11.1×10^{12} cfu/yr for Sepulcher Creek, 1.64×10^{14} cfu/yr for Toms Creek and 1.74×10^{14} cfu/yr in Crab Orchard Branch, and the TMDLs under average annual flow conditions are of 3.19×10^{12}, 2.56×10^{13} and 9.98×10^{12} cfu/yr, respectively. These values are used to calculate required reductions. By subtracting the waste load allocation (known value) from the TMDL (as computed), and the implicit margin of safety, the load allocation was determined. These values are presented in the following Table.

Table E1. Average annual *E. coli* loads and TMDL for Sepulcher Creek, Toms Creek including Little Toms, Little Toms Creek and Crab Orchard Branch watershed (cfu/yr.)

	WLA[1]	LA	MOS	TMDL
Sepulcher Creek	1.39×10^{10}	3.17×10^{12}	(implicit)	**3.19×10^{12}**
Toms Creek including Little Toms Creek	2.61×10^{10}	2.56×10^{13}	(implicit)	**2.56×10^{13}**
Little Toms Creek	1.04×10^{10}	8.53×10^{12}	(implicit)	**8.54×10^{12}**
Crab Orchard Branch	0.0	9.98×10^{12}	(implicit)	**9.98×10^{12}**

[1] The point source permitted to discharge in the Sepulcher Creek, Toms Creek including Little Toms Creek, Little Toms Creek and Crab Orchard Branch watershed are presented in section 5.2.

For the watersheds, the WLA represents less than 1% of the TMDL load. The required reductions of 71%, 84% and 94% respectively are to be applied to each of the four non-point sources identified in the BST analysis.

The Sepulcher Creek, Toms Creek and Crab Orchard Branch TMDL development presented in this report is the first step toward the attainment of water quality standards. The second step is to develop a TMDL implementation plan, and the final step is the field implementation of the TMDL to attain water quality standards.

The Commonwealth intends for this TMDL to be implemented through a process of phased implementation of best management practices (BMPs). The development of the Sepulcher Creek TMDL requires a 71% reduction in non-point source loading in order to attain a 0% violation of water quality standards. In order to evaluate interim reduction goals for a phased implementation plan, several reduction levels (70%, 60%, and 50%) and their associated violation rates were assessed. Reduction curves similar to the maximum exceedance/reduction curve were plotted and are presented in this report. The same process was undertaken for Toms Creek and Crab Orchard Branch as well.

Results also indicate that the violations occurred during times of precipitation and increasing stream flow or just after a precipitation event with stable or decreasing stream flow. This suggests that those violations could be related to runoff events. Some BMPs effective in reducing bacteria runoff from such precipitation events include: riparian buffers zone, retention ponds/basins, range and pasture management, and animal waste management. Detailed lists of BMPs and their relative effectiveness will be included in the eventual TMDL implementation plan for the watershed.

The development of the Sepulcher Creek, Toms Creek and Crab Orchard Branch TMDL would not have been possible without public participation. A public meeting was held in Tacoma, Virginia on October 17, 2002 to discuss the process for TMDL development and the source assessment input. Twenty-seven people attended. Copies of the presentation materials and the draft TMDL report were available for public distribution. The meeting was public noticed in the Virginia Register. There was a 30 day-public comment period and no written comment was received. The final public meeting was held January 26, 2004. Thirty-eight people attended the final meeting. There was a 30 day-public comment period, during which time, one written comment was received. These comments are submitted to EPA under separate cover.

1. Introduction

Section 303(d) of the Clean Water Act and US Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies which are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (EPA, 1991).

The Commonwealth of Virginia's (Virginia's) 1997 Water Quality Monitoring, Information, and Restoration Act (WQMIRA) codifies the requirement for the development of TMDLs for impaired waters. Specifically section § 62.1-44.19:7 C states:

"The plan required by subsection A shall, upon identification by the Board of impaired waters, establish a priority ranking for such waters, taking into account the severity of the pollution and the uses to be made of such waters. The Board shall develop and implement pursuant to a schedule total maximum daily loads of pollutants that may enter the water for each impaired water body as required by the Clean Water Act. "

The EPA specifies that in order for a TMDL to be considered complete and approvable, it must cover the following eight elements:

1. It must be designed to meet applicable water quality standards,
2. It must include a total allowable load as well as individual waste load allocations and load allocations,
3. It must consider the impacts of background pollution (such as wildlife),
4. It must consider critical environmental conditions or those conditions (stream flow, precipitation, temperature, etc.) which together can contribute to a worst-case exceedance of the water quality standard,
5. It must consider seasonal variations which together with the environmental variations can lead to a worst-case exceedance,
6. It must include an implicit or explicit margin of safety to account for uncertainties inherent in the TMDL development process,
7. It must allow adequate opportunity for public participation in the TMDL development process,
8. It must provide reasonable assurance that the TMDL can be met.

The following document details the development of a bacteria TMDL for three watersheds in the Guest River Basin which were listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Virginia's 2002 303(d) Report on Impaired Waters. A total of approximately seventeen stream miles were listed as impaired due to a violation of Virginia's water quality standard for fecal coliform bacteria.

A glossary of terms used throughout this report is presented as Appendix A.

2. Physical Setting

2.1. Listed Water Bodies

Sepulcher Creek, Toms Creek and Crab Orchard Branch are located in Wise County in the Guest River Subbasin and the Clinch River Basin (USGS Hydrologic Unit Code 06010205). The waterbody identification code (WBID, Virginia Hydrologic Unit) for Sepulcher Creek, Toms Creek and Crab Orchard Branch is VAS-P11R. The impaired segments are 2.6, 11.61 and 2.43 miles in length respectively. The impaired section of Sepulcher Creek begins at the headwaters and extends the entire length until confluence with Guest River. Sepulcher Creek flows through the communities of Glamorgan, Stephens and Addington. The entire length of Toms Creek is impaired, from the headwaters near Meade Chapel, through communities of Bondtown and Toms Creek, to the Guest River confluence at Coeburn. Little Toms Creek is a tributary to Toms Creek and is included in the impairment listing. Little Toms Creek parallels Route 58 between Banner and its confluence with Toms Creek in Coeburn. It also flows through the community of Vicco on Route 653 near its headwaters. Finally, Crab Orchard Branch, mistakenly labeled Crab Orchard Creek on the 303(d) list, is impaired from its headwaters to the Guest River confluence. Figure 1 shows a map of the watershed as well as the location of the flow and water quality stations on Sepulcher Creek, Toms Creek and Crab Orchard Branch. Table 1 presents a summary of the impairment listings for Sepulcher Creek, Toms Creek and Crab Orchard Branch.

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Figure 1. Map of the Sepulcher Creek, Toms Creek and Crab Orchard Branch study area

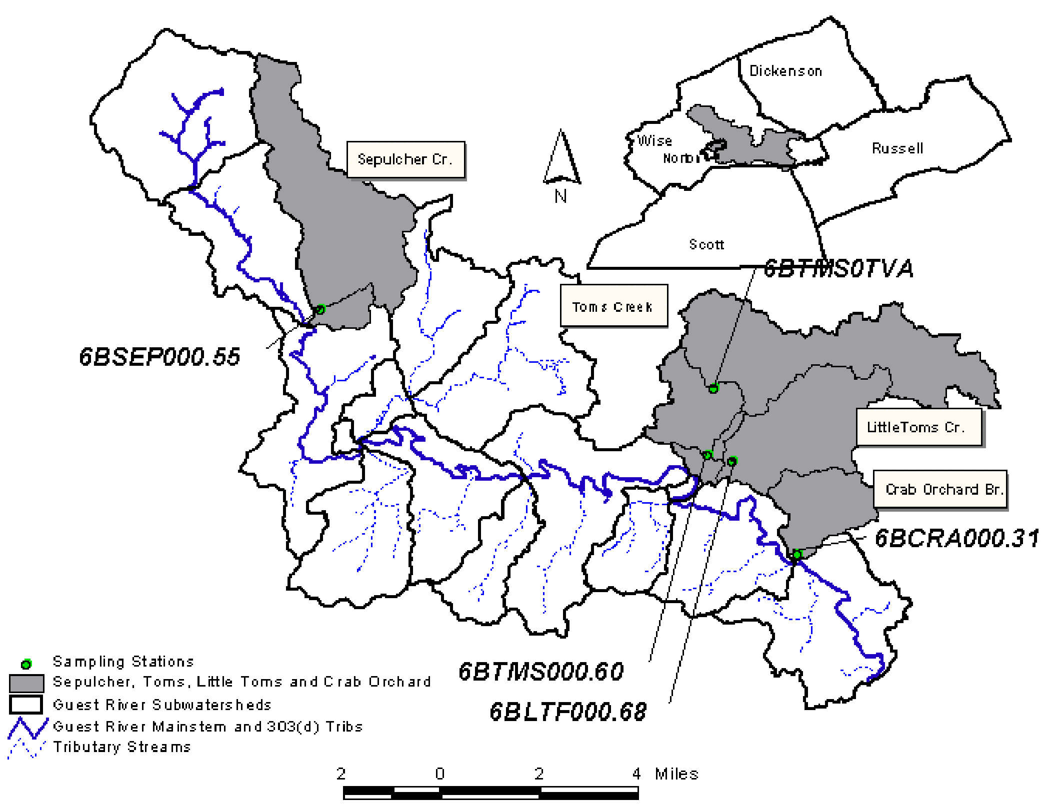

Table 1. Impaired segment description (from 2002 303(d) Report)

Segment (segment ID)	Impairment (source of impairment)	Upstream Limit Description	Downstream Limit Description	Miles Affected
Sepulcher Creek (VAS-P11R-07)	Fecal Coliform (NPS Urban)	Headwaters	Guest River confluence	2.6
Little Toms Creek (VAS-P11R-06)	Fecal Coliform (NPS Urban)	Headwaters	Toms Creek confluence	4.37
Toms Creek (VAS-P11R-08)	Fecal Coliform (NPS Urban)	Headwaters	Guest River confluence	11.6
Crab Orchard Branch (VAS-P11R-05)	Fecal Coliform (NPS Urban)	Headwaters	Guest River confluence	2.43

2.2. Watershed

2.2.1. General Description

The three watersheds, Sepulcher Creek, Toms Creek and Crab Orchard Branch are located in Wise County in the Guest River Subbasin and the Clinch River Basin (USGS Hydrologic Unit Code 06010205). The waterbody identification code (WBID, Virginia Hydrologic Unit) for Sepulcher Creek, Toms Creek, Little Toms Creek and Crab Orchard Branch is VAS-P11R. The impaired segments are 2.6, 11.6, 4.37 and 2.43 miles in length respectively.
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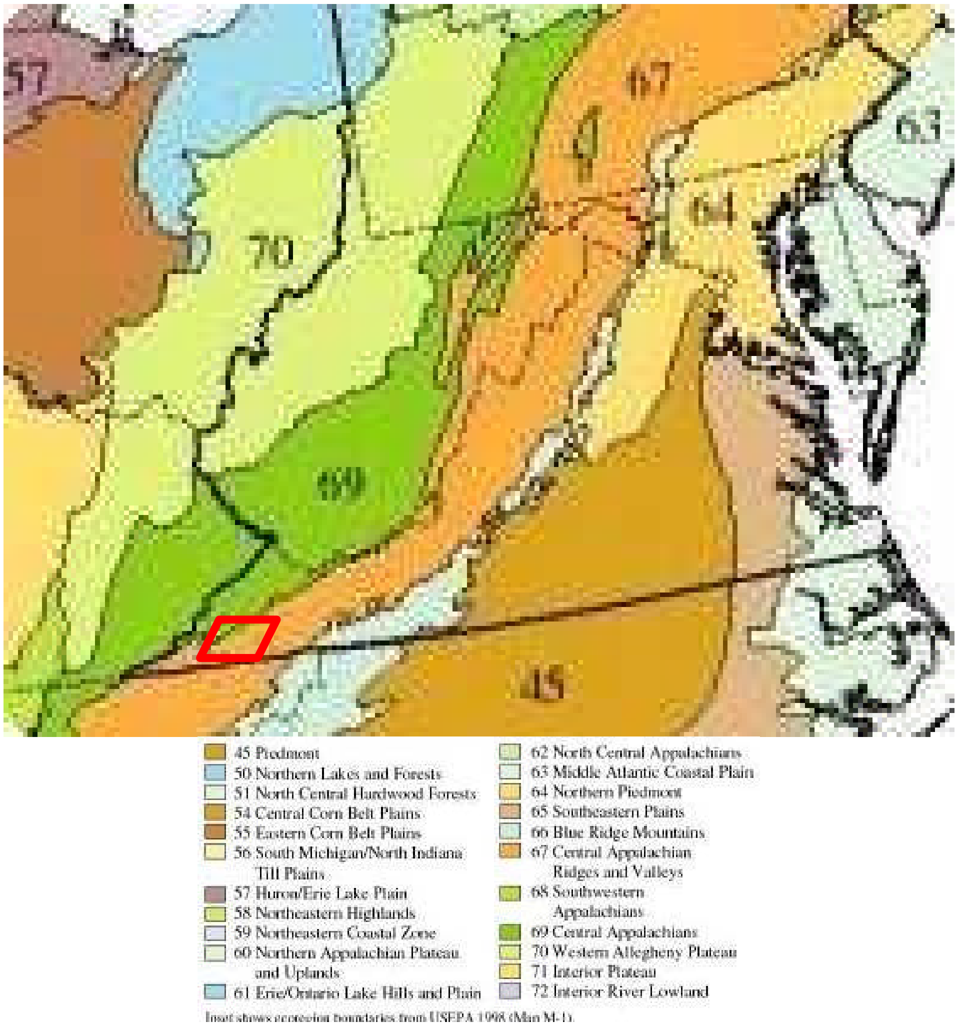
The Guest River flows southeast from its headwaters on Indian Mountain, through the towns of Norton and Coeburn. Guest River flows into Clinch River near the Wise County, Russell County line, downstream of Saint Paul, Virginia. The Clinch River flows southwest into Tennessee where it becomes part of the Tennessee River. The Tennessee River eventually discharges to the Mississippi River and flows to the Gulf of Mexico.

2.2.2. Geology, Climate, Land Use

Geology and Soils

Figure 2. Major ecoregion Level III Map within the Sepulcher Creek, Toms Creek and Crab Orchard Branch watersheds



Sepulcher Creek, Toms Creek and Crab Orchard Branch watersheds are located in Wise County and are part of the Central Appalachian ecoregion (Figure 2). An ecoregion is an informative natural division providing insight and perspective on stream quality (EPA 2002). Ecoregions, which are areas that have similar soils, vegetation, climate, and physical geography, are identified for the entire US, including the Mid-Atlantic Highlands. The map, in Figure 2, shows "Level III" Ecoregions. The types of stream problems, and stressors creating these problems, become more apparent from the characteristics of the ecoregions.

Differences among ecoregions are useful for determining land use stressors. For example, mountains with their steep slopes, shallow soils, and cooler climate are very different from valleys that are relatively flat, have deep soils, and warmer temperatures. Mountain ridges might represent one ecoregion while valleys would represent a different ecoregion. Mountain streams have a different quality than valley streams. An ecoregion perspective also helps us understand why streams respond to various human disturbances as they do and which management solutions might be applicable. The Guest River is located in the Central Appalachian ecoregion, stretching from central Pennsylvania to northern Tennessee. The Central Appalachian ecoregion is primarily a high, dissected, rugged plateau composed of sandstone, shale, conglomerate, and coal. The rugged terrain, cool climate, and infertile soils limit agriculture, resulting in a mostly forested land cover. The high hills and low mountains are covered by a mixed mesophytic forest with areas of Appalachian oak and northern hardwood forest. The southern part of the ecoregion in West Virginia is primarily a forested plateau composed of sandstone and shale geology and coal deposits. Due to the rugged terrain, cool climate, and infertile soils, this area is more forested and contains much less agriculture than the Valley and Western Appalachian ecoregions. Resource extraction of bituminous coal is a major industry in this region and acid mine drainage and stream siltation associated with coal mining is common.

Sepulcher Creek, Toms Creek and Crab Orchard Branch geology consists of sandstone, shale, clay and coal. It is in the Appalachian Plateau physiographic province. There are areas of high relief with steep-sided valleys drained by these tributaries to Guest River. The average elevation is between 2000 and 2500 feet. The streams generally have a steep gradient ranging from 10 percent slopes to 40 percent slopes. Areas which have been strip mined have slopes up to 55 percent. Soils within the watersheds are sandy loam or clay due to the sandstone composition of the bedrock layers.

The Norton and Wise formations and Gladesville sandstone make up the geologic components of the region. These formations are in the Pennsylvanian Series of the Carboniferous system according to *U.S.G.S. Survey Bulletin No. XXIV*. Some of the sandstones and conglomerates are so resistant to weathering that they result in plateaus and outcrops of stone. These features are apparent in the Guest River Gorge towards the mouth of Guest River. Where slopes are very steep, removing trees and forest cover causes soils to erode quickly so that pasture or cultivation is not possible.

The geologic structure of the basin varies from horizontal formations to angled formations. That is, rather than a uniform horizontal thickness to each layer of either sandstone, clay, coal and shale, these fold and the thickness of each varies. Given the properties of each rock layer, their deformities vary. The harder stone will buckle whereas the softer stones may thin. Due to these deformities in the geologic formations, the location of the coal layers varies from the land surface to deep underground.

Coal availability and extraction occurs in the upper Guest River watershed and along the Rocky Fork, Sepulcher Creek sub-watersheds. Mines exist on Toms Creek and Little Toms Creek as well. In the first half of the twentieth century, Wise County produced coke from the coal, limestone and lumber resources in this drainage. Lumber removed from steep slopes causes the soil mantle to quickly wash away.

Climate

The climate in Wise County is moderate. A monthly climate summary for the weather data from a weather station, located in the town of Wise, is presented in Table 2 below.

Table 2: Climate Data for Wise County, Virginia

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Annual
Avg. Max. Temp.(F)	41.9	46.1	55.0	65.2	72.4	78.2	81.0	80.2	75.1	66.1	55.1	45.3	63.5
Avg.Min. Temp. (F)	23.5	26.4	33.5	42.2	49.9	56.7	60.7	59.6	53.6	43.0	35.0	27.4	42.6
Avg.Total Rainfall (in.)	3.69	3.88	4.44	4.09	4.35	4.01	5.28	3.95	3.45	2.78	3.48	3.52	46.91
Avg.Total Snowfall (in.)	13.2	11.6	8.0	2.2	0.1	0.0	0.0	0.0	0.0	0.2	2.8	8.4	46.5

Wise 1 SE, Virginia (449215)Period of Record: 5/12/1955 to 7/31/2003
From Southeast Regional Climate Center, sercc@dnr.state.sc.us

Land Use

A Benthic TMDL for Guest River, the river to which these impaired watersheds drain, was completed and approved by EPA in November 2003. As part of the benthic TMDL, the Tennessee Valley Authority developed a predictive water quality loading model based on data gained by low flight, infrared, aerial photography interpretation. (Guest River Watershed NPS Pollution Inventory and Pollutant Load Estimates TVA June 2003) The photographs were taken in the spring of 2001 before tree leaf-out so that an optimum view of the land surface was acquired. The following land use discussions are based on the aerial photograph interpretation. These land uses were verified with local agencies before the final numbers were determined.

Sepulcher Creek

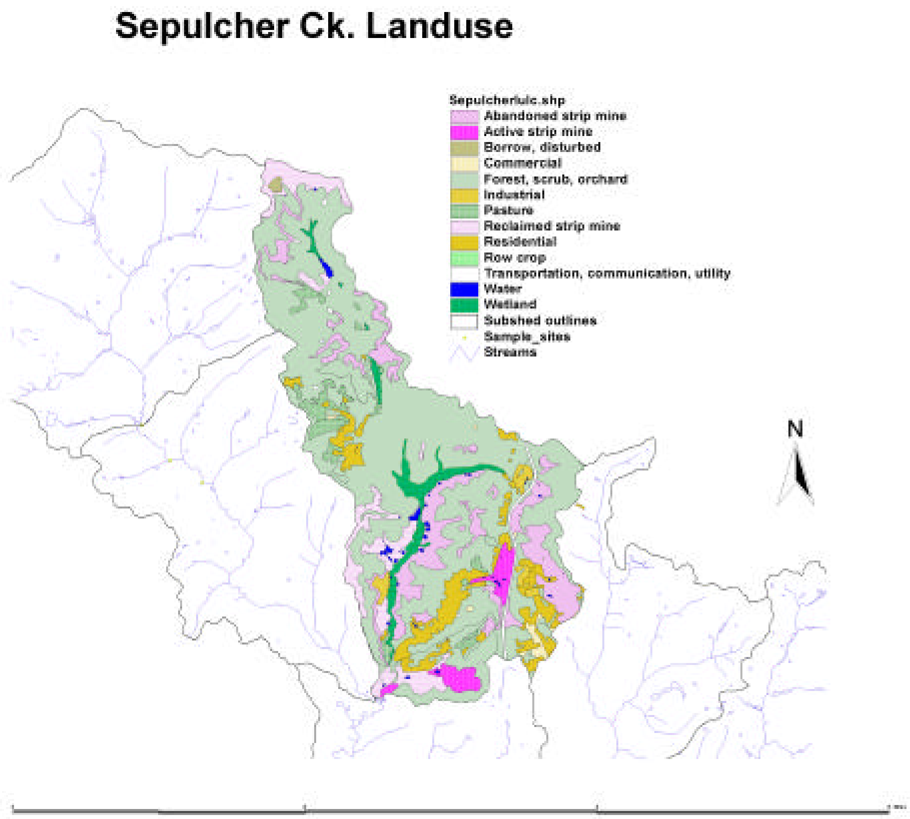
The Sepulcher Creek watershed extends approximately 5.5 miles upstream from the stream confluence with Guest River and is approximately 3 miles wide. Rocky Fork Creek is a tributary to Sepulcher Creek and extends the furthermost northward from their confluence. The 5,620 acre watershed is predominately forested (61percent), with 12 percent abandoned strip mine lands, 7.4 percent reclaimed strip mine land and 7.3 percent residential use. The remaining 12 percent of the watershed consist of pasture, strip mining, wetland, commercial, industrial, transportation and utility, borrow, and open water (Table 3). A map of the distribution of land use in the watershed (Figure 3) indicates that homes are clustered along Sepulcher Creek and agriculture is located along the Rocky Fork tributary. Forests are located on the mountains where the steep slopes preclude other land uses.

Table 3. Land use in the Sepulcher Creek watershed

Land Use Category	Area (acres)	Area (%)
Residential	410.5	7.3
Commercial	33.7	0.6
Industrial	67.5	1.2
Transportation,Communication, Utility	50.6	0.9
Pasture	174.3	3.1
Forest, scrub, orchard	3424.3	60.9
Open Water	33.7	0.6
Active Strip Mine	129.3	2.3
Reclaimed Strip Mine	416.1	7.4
Abandoned Strip Mine	686.0	12.2
Borrow, disturbed	11.2	0.2
Wetland	185.6	3.3
Total	5622.8	100.00

Source: Guest River Watershed NPS Pollution Inventory and Pollutant Load Estimates TVA June 2003

Figure 3. Land Use Map of the Sepulcher Creek Watershed



Toms Creek Watershed

Toms Creek watershed is approximately 3 miles wide and extends about 8 miles upstream from its confluence with Guest River. The 7,035-acre watershed is predominately forested (58 percent), with 12. percent abandoned strip mine lands, 6.4 percent active mining, 10 percent residential and 8 percent pasture use. The remaining 5 percent of the watershed consist of commercial, industrial, wetland, industrial, transportation and utility, borrow, and open water (Table 4). Little Toms Creek is a major tributary to Toms Creek. With 3,516.2 acres in this watershed, it is almost half as large as the area in Toms Creek. Table 5 illustrates the similarities between the two watersheds and the percent of each land use. A map of the distribution of land use in the watersheds (Figure 4) indicates that residences and row crops are concentrated along the streambanks and forest is along the slopes. This is due to the hilly terrain in the watershed. Steep slopes of the mountains parallel the streams to the east and west.

Table 4. Land use in the Toms Creek and Little Toms Creek watersheds

Land Use Category	Toms Creek		Little Toms Creek	
	Area (acres)	Area (%)	Area (acres)	Area (%)
Residential	686.9	9.8	451.2	12.8
Commercial	168.8	2.4	72.2	2.1
Industrial	6.8	0.1	0.8	0.01
Transportation,Communication, Utility	62.2	0.9	164.3	4.7
Pasture	570.1	8.1	104.6	3.0
Forest, scrub, orchard	4100.5	58.3	2254.1	64.1
Open Water	22.2	0.3	3.6	0.1
Active Strip Mine	453.3	6.4	0.0	0
Reclaimed Strip Mine	27.1	0.4	0.0	0
Abandoned Strip Mine	869.4	12.4	465.4	13.2
Wetland	60.9	0.9	0	0
Totals	7035.1	100.0	3516.2	100.0

Source: Guest River Watershed NPS Pollution Inventory and Pollutant Load Estimates TVA June 2003

Toms Creek and Little Toms Creek Land Use

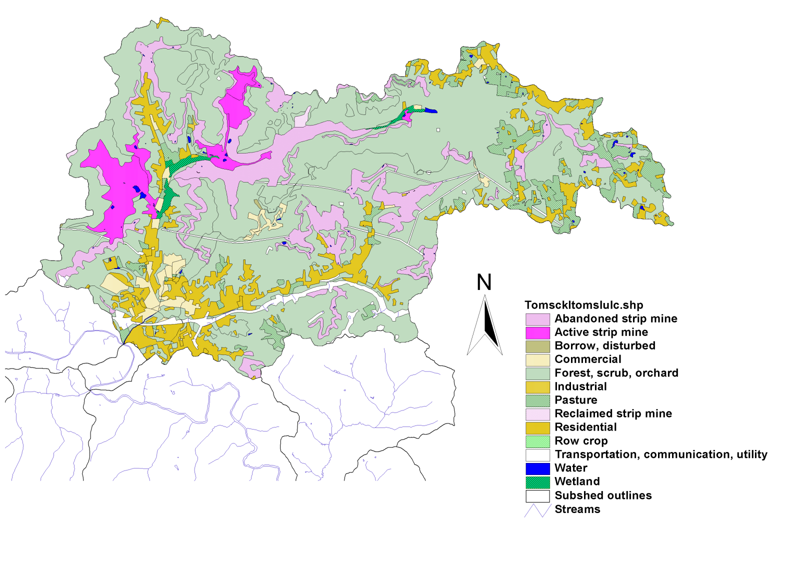


Figure 4. Land Use Map of the Toms Creek Watershed

Crab Orchard Branch Watershed

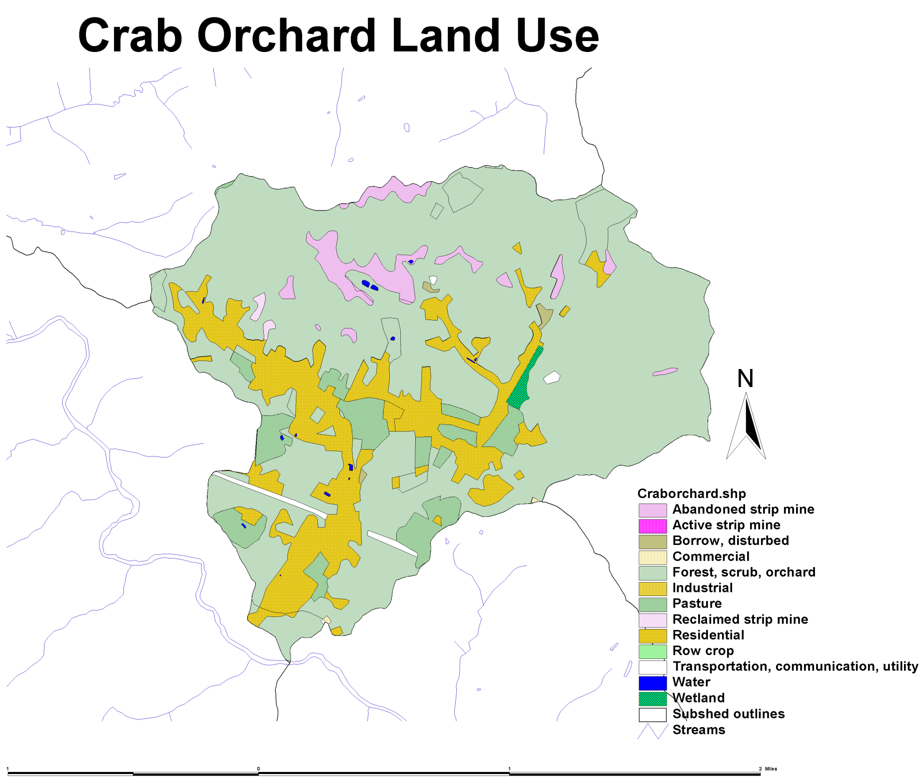
Crab Orchard Branch watershed is approximately 2 miles wide and 2 miles upstream from its confluence with Guest River. The 1,715-acre watershed is predominately forested (72.4 percent), with nearly 17 percent residential and 6 percent pasture. The remaining 5 percent of the watershed consist of abandoned strip mining, wetland, industrial, transportation and utility, borrow, and open water (Table 5). A map of the distribution of land use in the watershed (Figure 5) indicates that most of the homes are beside the streams. The land that is flat enough to make housing feasible is along the streambanks. Crab Orchard Branch topography and land use patterns mirror those in Toms Creek and Sepulcher Creek watersheds.

Table 5. Land use in the Crab Orchard Branch watershed

Land Use Category	Area (acres)	Area (%)
Residential	284.7	16.6
Transportation, Communication, Utility	10.3	0.6
Pasture	106.3	6.2
Forest, scrub, orchard	1241.66	72.4
Open Water	1.7	0.1
Reclaimed Strip Mine	3.4	0.2
Abandoned Strip Mine	56.6	3.3
Borrow, disturbed	3.4	0.2
Wetland	6.9	0.4
Total	1715	100.00

Source: Source: Guest River Watershed NPS Pollution Inventory and Pollutant Load Estimates TVA June 2003

Figure 5. Land Use Map of the Crab Orchard Branch Watershed



3. Description of Water Quality Problem/Impairment

Sepulcher Creek, Toms Creek, Little Toms Creek and Crab Orchard Branch were listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 1998) and the 2002 303(d) Report on Impaired Waters (VADEQ, 2002) due to violations of the State's water quality standard for fecal coliform bacteria. These streams were sampled in 1996 as part of a special study organized by Tennessee Valley Authority and Department of Environmental Quality. Since multiple samples were collected within a month, the geometric mean as well as the instantaneous criteria were used to determine violations. Stations on each stream are shown in Figure 6 and Table 6 is a summary table of data. The following paragraphs address each stream.

Sepulcher Creek

The water quality monitoring station on Sepulcher Creek, station 6BSEP000.55, is about half mile above the confluence with Guest River. Initially, in 1996, this site was the only station on the stream and was identified as the railroad station because of the proximity of the railroad to the site. Eleven samples were collected at the railroad site during the summer (June and July) of 1996. The resulting geometric means were 158 colony forming units per 100 milliliters of sample water (cfu/100 ml) and 457 cfu/100 ml, the second one exceeded the fecal coliform geometric mean value of 200 cfu/100 ml thereby becoming a candidate impaired water. Samples were collected in March 1999 with a geometric mean result of 37 cfu/100 ml. In 2000, samples were collected at 6BSEP000.55, from January to August with all geometric means falling below the Virginia geometric mean standard. In 2001, results from June also show that the geometric mean complies with the water quality criteria. The second station was established in March of 1999 and a series of March 1999 samples had a geometric mean of 212 cfu/100 ml. In January 2000 this upstream station, 6BSEP00TVA, was sampled again with a geometric mean result of 364 cfu/100 ml. In 2001, only the railroad site, the downstream site was sampled with resulting geometric mean of 66. The stream remained on the 2002 TMDL list because the most recent data at the upstream site indicates there was a fecal coliform problem.

Toms Creek

Toms Creek station 6BTMS000.60, data had a geometric mean of 2,970 and 2,448 cfu/100 ml for the June and July 1996 samples. Little Toms Creek July 1996 data had a geometric mean of 1,950 cfu/100 ml. The one sampling event in June 1996 had 940 cfu/100 ml fecal coliform. Both sites clearly violated the fecal coliform geometric mean criterion and were listed for not supporting the swimmable use on the 1998 303(d) TMDL list. Data collected since the initial listing indicate a decreasing trend in fecal coliform contamination, however there are still violations of the instantaneous criteria so that they have remained on the TMDL list for not supporting the swimmable use.

Crab Orchard Branch

Crab Orchard Branch, station 6BCRA000.31, had geometric means of 985 cfu/100 ml and 578 cfu/100 ml during the same 1996 sampling timeframe. Six of the 11 samples for Crab Orchard Branch were higher than 1000 in 1996. In the subsequent 2002 assessment period, Crab Orchard Branch had no violations of 16 samples. Summer of 2001data collected on Crab Orchard Branch resulted in a geometric mean of 202 which is a violation of the standard so Crab Orchard Branch was retained on the 303(d) List for bacteria violations.

Figure 6. Map of the Sepulcher Creek, Toms Creek and Crab Orchard Branch Sampling Stations

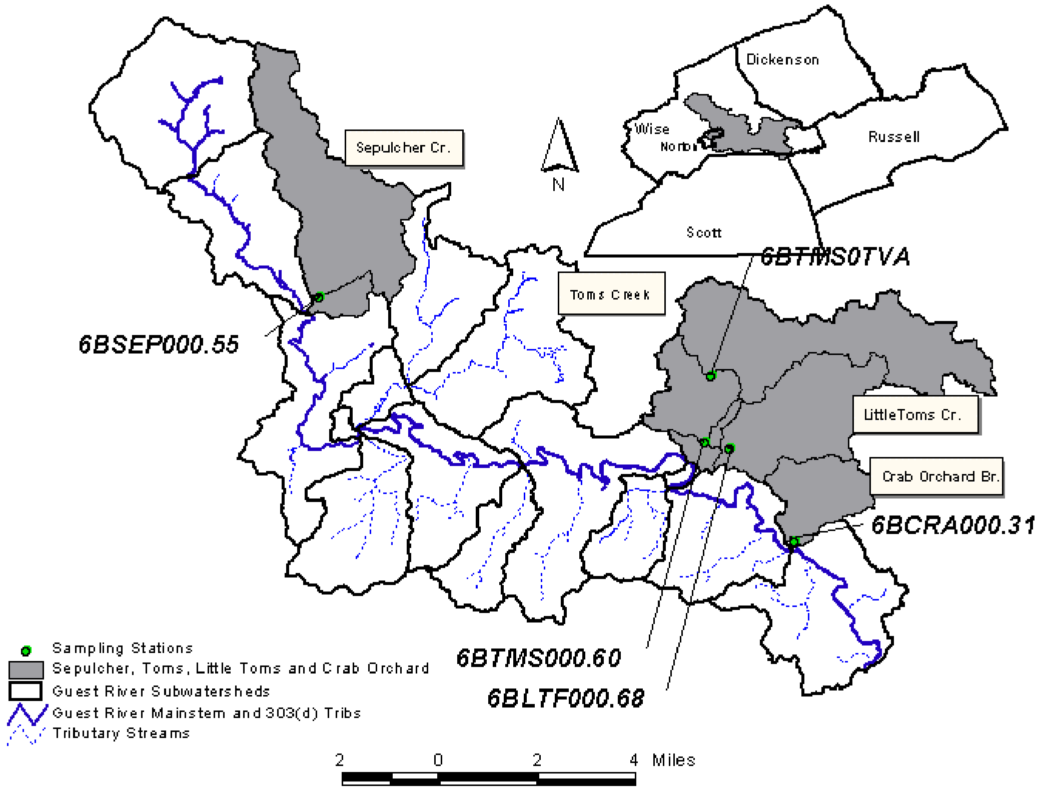


Table 6. Fecal coliform data compiled by TVA on Sepulcher Creek, Toms Creek, Little Toms Creek and Crab Orchard Branch

Station	Date of First Sample	Date of Last Sample	Number of Samples	Average	Minimum	Maximum	Number of Exceed-ances*	Max. Geom. Mean*
6BSEP00TVA	3/9/1999	6/24/2002	25	672	10	2220	9	364
6BSEP000.10	6/12/1996	6/24/2002	75	138	5	1520	1	457
6BTMS000.60	6/12/1996	6/24/2002	46	1147	5	4980	13	2970
6BLTF000.10	6/26/1996	6/24/2002	45	625	5	5200	7	1950
6BCRA000.40	6/12/1996	6/24/2002	49	704	5	5000	6	985

- Exceedances of the fecal coliform instantaneous standard of 1,000 cfu/100 ml, and the Geometric Mean standard of 200 cfu/100 ml

In 2002, DEQ began sampling the streams, collecting fecal coliform bacteria data, e.coli. bacteria data and the samples were sent to MapTech, Inc. for analysis for BST information as well as enumeration. This additional data collected for the TMDL study is discussed later.

4. Water Quality Standard

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term *"water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."*

As stated above, Virginia water quality standards consist of a designated use or uses and a water quality criteria. These two parts of the applicable water quality standard are presented in the sections that follow.

4.1. Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10A), *"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

As stated above, Sepulcher Creek, Toms Creek and Crab Orchard Branch must support all designated uses and meet all applicable criteria.

4.2. Applicable Water Quality Criteria

The applicable water quality criteria for bacteria in the Sepulcher Creek, Toms Creek and Crab Orchard Branch watershed have changed since the initial listing on the 303(d) report. Following EPA recommendations, the Virginia Department of Environmental Quality (DEQ) proposed more stringent fecal coliform bacteria standards as well as new standards for *Escherichia coli* (*E. coli*) bacteria. These new standards were adopted by the State Water Control Board in May 2002, public noticed in June 2002, approved by the USEPA in November 2002, and were effective January 15, 2003.

The EPA recommendation that states adopt *E. coli* and enterococci (saltwater) standards stems from a stronger correlation between the concentration of *E. coli* and enterococci organisms and the incidence of gastrointestinal illness. *E. coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. *E. coli* is a subset of fecal coliform group; thus, a waterbody listed as impaired for fecal coliform is considered to be listed for *E. coli* as well.

Although Sepulcher Creek, Toms Creek and Crab Orchard Branch were listed as impaired due to a violation of the previous fecal coliform standard, the TMDL must be developed to meet the new *E. coli* bacteria standard. The interim fecal coliform bacteria standard presented below will not apply to this TMDL since 12 *E. coli* bacteria samples were collected as part of the bacteria source tracking study for the source assessment.

New Bacteria Standards

For a non-shellfish supporting water body such as Sepulcher Creek, Toms Creek and Crab Orchard Branch to be in compliance with Virginia bacteria standards for primary contact recreational use, the DEQ specifies the following criteria (9 VAC 25-260-170):

1. Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water. This criterion shall not *apply for a sampling station after the bacterial indicators described in subdivision 2 of this subsection have a minimum of 12 data points or after June 30, 2008, whichever comes first.*

2. E.coli and enterococci bacteria per 100 ml of water shall not exceed the following:

Table 7. Applicable water quality standards

Parameter	Geometric Mean[1] (cfu/100 ml)	Single Sample (cfu/100 ml)
E.coli (fresh water)	126	235
Enterococci (saltwater & Transition Zone 3)	35	104

[1] for two or more samples taken during a calendar month.

If the waterbody exceeds the criterion as listed above more than 10 percent of the time, the waterbody is classified as impaired and a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality criterion. Based on the sampling frequency, only one criterion is applied to a particular datum or data set (9 VAC 25-260-170). If the sampling frequency is one sample or less per calendar month, the instantaneous criterion is applied; for a higher sampling frequency, the geometric mean criterion is applied.

For Sepulcher Creek, Toms Creek and Crab Orchard Branch, the TMDL is required to meet the instantaneous criterion since the load-duration approach used to develop the TMDL for Sepulcher Creek, Toms Creek and Crab Orchard Branch yields the maximum allowable bacteria concentration under any given flow condition. Unlike a continuous time series simulation, the flow duration approach does not yield daily bacteria concentrations that are needed to apply the geometric mean standard. Such an approach ensures that TMDLs, when implemented, do not result in violations under a wide variety of scenarios that affect bacteria loading.

5. Assessment of Bacteria Sources

The assessment of bacteria sources in traditional bacteria TMDL studies involves estimating loads from sources in the watershed and developing a computer model to establish the links between estimated loads and actual in-stream bacteria concentrations.

In a load-duration bacteria TMDL, source assessment is accomplished by determining the relative contribution, by source, of the fecal bacteria contained in a sample of stream water. This method of source identification is achieved through microbial source tracking (MST). MST methods that specifically use bacteria as the target organism are referred to collectively as bacteria source tracking (BST) methods. MST has been applied to study microbial ecology of environmental systems for years and are now being applied to help improve water quality by identifying problem sources and determining the effect of implemented remedial solutions. Management and remediation of water pollution would be more cost effective if the correct sources could be identified (Simpson, 2002).

To support BST analyses in load-duration TMDLs, bacteria loading in a watershed is also estimated. These load estimates are broken into point and non-point sources. It is important to note that the non-point source load estimates represent loading to the surface of the watershed; they are not estimates of in-stream loads.

The following sections present BST analysis and point- and non-point source load estimates.

5.1. Bacteria Source Tracking (BST)

Background

MST methods can be divided into three categories: molecular (genotype), biochemical (phenotype), and chemical. Molecular methods may offer the most precise identification of specific types of sources but are limited by high per-isolate costs and detailed and time-consuming procedures. They are not yet suitable for assaying large numbers of samples in a reasonable period. Biochemical methods (BST) may or may not be as precise, but are more simple, quicker, less costly, and allow large numbers of samples to be assayed in a short period of time (Hagedorn, 2002).

Several biochemical BST methods are in various stages of development. Among these are Antibiotic Resistance Analysis (ARA), F-Specific (F+ or FRNA) Coliphage, Sterols or Fatty Acid Analysis, Nutritional Patterns, and Fecal Bacteria Ratios. Of these, ARA has been chosen as the BST method for this TMDL report.

The ARA method uses fecal streptococcus (including the enterococci) and/or *E. coli* and patterns of antibiotic resistance for separation of sources. The premise is that human fecal bacteria will have the greatest resistance to antibiotics and that domestic and wildlife animal fecal bacteria will have significantly less resistance (but still different) to the battery of antibiotics and concentrations used. Most investigators are testing each isolate on 30 to 70+ antibiotic concentrations (Hagedorn, 2002). A more detailed description of the ARA method used by MapTech, Inc. in support of this TMDL is presented in Appendix B.

BST Sampling and Results

A total of 12 ambient water quality samples were collected by DEQ staff and submitted to MapTech, Inc. (MapTech) for BST analysis. The BST analyses performed by MapTech determined the relative contribution of overall bacteria by human, pet, livestock, and wildlife sources. Fecal and *E.coli* bacteria were also enumerated as part of the analyses performed by MapTech. Results of the Sepulcher Creek, Toms Creek and Crab Orchard Branch BST sampling program are presented in Tables 8, 9, 10 and 11.

Sepulcher Creek

Table 8. Sepulcher Creek bacteria source tracking results at station 6BSEP000.55

Sample Date	Fecal Coliform (cfu)	*E. coli* (cfu)	BST Distribution			
			Human	Pet	Livestock	Wildlife
09/05/2002	240	40	4%	17%	21%	58%
10/23/2002	60	50	45%	17%	21%	17%
11/21/2002	260	100	10%	60%	30%	0%
12/16/2002	440	120	0%	33%	54%	13%
01/27/2003	80	1	--	--	--	--
02/18/2003	280	20	0%	50%	50%	0%
03/04/2003	200	140	33%	21%	42%	4%
04/21/2003	430	24	0%	0%	38%	62%
05/21/2003	2500	820	29%	8%	8%	55%
06/09/2003	450	200	17%	41%	25%	17%
07/14/2003	270	62	4%	0%	8%	88%
08/20/2003	210	54	21%	21%	45%	13%
		Average	15%	24%	31%	30%
		Standard Deviation	15%	20%	16%	30%

The BST data results indicate that the majority bacteria are coming from anthropogenic sources. Approximately 70% of the bacteria found in the Sepulcher Creek study comes from human, pet, or livestock sources.

Toms Creek

Table 9. Toms Creek bacteria source tracking results at station 6BTMS000.60

Sample Date	Fecal Coliform (cfu)	*E. coli* (cfu)	BST Distribution			
			Human	Pet	Livestock	Wildlife
09/05/2002	2000	410	21%	25%	0%	54%
10/23/2002	1000	220	4%	33%	30%	33%
11/21/2002	900	660	34%	33%	33%	0%
12/16/2002	360	100	13%	13%	74%	0%
01/27/2003	150	20	56%	6%	13%	25%
02/18/2003	490	65	0%	13%	0%	87%
03/04/2003	460	110	25%	33%	4%	38%
04/21/2003	640	150	0%	0%	100%	0%
05/21/2003	4000	1500	0%	17%	75%	8%
06/09/2003	2700	310	25%	13%	41%	21%
07/14/2003	800	200	13%	0%	13%	74%
08/20/2003	3700	290	13%	13%	57%	17%
		Average	17%	17%	37%	30%
		Standard Deviation	17%	12%	33%	29%

Table 10. Little Toms Creek bacteria source tracking results at station 6BLTF000.68

Sample Date	Fecal Coliform (cfu)	*E. coli* (cfu)	BST Distribution			
			Human	Pet	Livestock	Wildlife
11/21/2002	2100	1200	4%	4%	92%	0%
12/16/2002	3200	350	0%	13%	83%	4%
01/27/2003	850	480	0%	0%	25%	75%
02/18/2003	880	220	33%	25%	21%	21%
03/04/2003	510	64	33%	4%	8%	55%
04/21/2003	2000	240	4%	33%	30%	33%
05/21/2003	8900	1700	17%	21%	62%	0%
06/09/2003	800	290	8%	17%	8%	67%
07/14/2003	2000	440	4%	13%	8%	75%
08/20/2003	68000	2000	42%	54%	4%	0%
		Average	15%	18%	34%	33%
		Standard Deviation	15%	15%	31%	31%

The BST data results indicate that the majority bacteria are coming from anthropogenic sources. Approximately 67% of the bacteria in Little Toms Creek and 70% of the bacteria found in the Toms Creek study comes from human, pet, or livestock sources. These are similar enough to consider these streams one TMDL study area.

Crab Orchard Branch

Just as with the other study areas in Sepulcher Creek and Toms Creek, the BST data results indicate that the majority of bacteria are coming form anthropogenic sources. Approximately 66% of the bacteria found in the Crab Orchard Branch watershed comes from human, pet, or livestock sources. Note, however, that in this watershed, there is a higher portion from human sources and a lower portion contributed to livestock. These estimates agree with the land use differences between the watersheds.

Table 11. Crab Orchard Branch bacteria source tracking results at station 6BCRA000.31

Sample Date	Fecal Coliform (cfu)	*E. coli* (cfu)	BST Distribution			
			Human	**Pet**	**Livestock**	**Wildlife**
09/05/2002	8400	1300	13%	8%	0%	79%
10/23/2002	2000	140	8%	21%	4%	67%
11/21/2002	720	200	14%	14%	72%	0%
12/16/2002	2000	150	25%	29%	29%	17%
01/27/2003	650	220	0%	8%	29%	63%
02/18/2003	5000	22	44%	56%	0%	0%
03/04/2003	8000	610	53%	7%	20%	20%
04/21/2003	770	58	74%	4%	0%	22%
05/21/2003	8000	4100	0%	38%	17%	45%
06/09/2003	3200	230	38%	16%	8%	38%
07/14/2003	3600	130	17%	13%	13%	57%
08/20/2003	4400	690	38%	38%	24%	0%
		Average	27%	21%	18%	34%
		Standard Deviation	22%	15%	20%	27%

5.2 Point Sources

Bacteria loading from point sources such as sewage treatment plants, small commercial establishments, schools, homes and businesses require permits under the Virginia Pollution Discharge Elimination System (VPDES) permit program. In order to consider all such point-source discharges in the Sepulcher Creek, Toms Creek and Crab Orchard Branch watershed, the DEQ comprehensive environmental database and regional DEQ permit staff were queried. There are no minor or major municipal discharge permits identified in the watersheds.

There are, however homes and small businesses with permits in the watersheds. There are five residences with discharge permits for sewage treatment plant units (STP) on Sepulcher Creek and three residence STP units on an unnamed tributary (UT) to Sepulcher Creek. Ten discharge permits are within the Toms Creek watershed; nine residential STP units and one minor industrial discharge permit. Two residence STP units discharge to Little Toms Creek and four more residence STP units discharge to unnamed tributaries to Little Toms Creek. There are no permitted VPDES discharges in Crab Orchard Branch watershed. The following table (Table 12) lists the point source discharges in the Sepulcher Creek and Toms Creek watersheds.

Table 12. VPDES Point Source Facilities and Fecal Coliform Bacteria Loads

Stream Name	Facility Name	VPDES Permit Number	Discharge Type	Design Flow (gal/day)	Permitted Concentration (cfu/100mL)	Permitted Load (cfu/yr)
Sepulcher Ck	Thad Zylawy Res. STP	VAG400267	General	1000	126	1.74×10^9
Sepulcher Ck	Ward A. Miller Res. STP	VAG400348	General	1000	126	1.74×10^9
Sepulcher Ck	Paul C. Rains Res. STP	VAG400289	General	1000	126	1.74×10^9
Sepulcher Ck	Jackie Fleming Res. STP	VAG400449	General	1000	126	1.74×10^9
Sepulcher Ck	Jeff Perry Res.STP	VAG400454	General	1000	126	1.74×10^9
Sepulcher Ck, UT	Kathy & Gary Selvage Res.STP	VAG400427	General	1000	126	1.74×10^9
Sepulcher Ck, UT	Clark Mitchell Res.STP	VAG400255	General	1000	126	1.74×10^9
Sepulcher Ck, UT	Edward A. Miller Res.STP	VAG400348	General	1000	126	1.74×10^9
Sepulcher Totals						**$1.39\text{x}10^{10}$**
Toms Creek	Toms Creek WTP*	VA0052388	Industrial	2500	N/a	N/a
Toms Creek	VICC Toms Ck STP	VAG400197	General	1000	126	1.74×10^9
Toms Creek	D&J Feed Inc. STP	VAG400246	General	1000	126	1.74×10^9
Toms Creek	John Ring Trucking Inc.STP	VAG400247	General	1000	126	1.74×10^9
Toms Creek	Reaching Up Higher Christian Church STP	VAG400301	General	1000	126	1.74×10^9
Toms Creek	Delia Salyers Res.STP	VAG400419	General	1000	126	1.74×10^9
Toms Creek	Sandra Couch Residence STP	VAG400300	General	1000	126	1.74×10^9
Toms Ck,UT	Michael G. Burke Res.STP	VAG400390	General	1000	126	1.74×10^9
Toms Ck,UT	Bruce & Joyce Martin Res. STP	VAG400393	General	1000	126	1.74×10^9
Toms Ck,UT	Bruce Martin Res. STP	VAG400294	General	1000	126	1.74×10^9
Little Toms Ck.	Jackie Boyd Res. STP	VAG400467	General	1000	126	1.74×10^9
Little Toms Ck.	Lois Couch Res.STP	VAG400305	General	1000	126	1.74×10^9
Little Toms Ck.,UT	Michael Crawford Res.STP	VAG400357	General	1000	126	1.74×10^9
Little Toms Ck.,UT	Bobby C. Ketron Res. STP	VAG400433	General	1000	126	1.74×10^9
Little Toms Ck.,UT	Dale Couch Res. STP	VAG400457	General	1000	126	1.74×10^9
Little Toms Ck.,UT	Joe & Blanche Bright Res. STP	VAG400362	General	1000	126	1.74×10^9
Total Toms Ck and Little Toms Ck.						**$2.61\text{x}10^{10}$**

* Toms Creek Water Treatment Plant (WTP) has no permit limit for bacteria

Permitted loads were calculated by multiplying the permitted discharge concentration (126 cfu/100 ml) times the design flow (1,000 gal/day) times the appropriate unit conversions (37.85). The calculation is presented in Appendix C. Each residence uses chlorine to disinfect wastewater.

5.3. Non-Point Sources

In order to gain an understanding of non-point source loading in the Sepulcher Creek, Toms Creek and Crab Orchard Branch watersheds, bacteria loads for typical non-point sources were estimated. These estimates were based upon animal and human population data sets, typical waste production rates and typical bacteria densities in waste products. The estimates for Toms Creek included the Little Toms Creek sub-watershed.

Currently published values for fecal bacteria production rates are primarily in terms of fecal coliform. There is little data on *E. coli* production; however, studies have shown that though minor variability will exist between sources, *E. coli* represents roughly 90-95% of fecal coliform contained in "as-excreted" fecal material (Yagow, 2002). This implies that the relative bacteria contribution by source should remain constant.

It is important to note that the bacteria loads presented in the following sections on non-point sources represent "as-produced" loads. This is to say that some portion of an estimated load may not be available to be transported to Sepulcher Creek, Toms Creek and Crab Orchard Branch in runoff.

5.3.1. Humans and Pets

Bacteria loading from human sources can come from straight pipes, failing septic systems, and land-applied biosolids. Failing septic systems are typically manifested by effluent discharging to the ground surface where the bacteria laden effluent is then available to be washed into a stream as runoff during a precipitation event. In contrast, discharges from straight pipes are typically directly deposited to streams.

All biosolids can contain a certain concentration of fecal bacteria. When biosolids are applied to the land surface, the potential exists for a portion of these fecal bacteria to be transported to a stream as runoff during storm events.

Straight Pipes and Septic Systems

Based on 2000 U.S. Census data, the Sepulcher Creek, Toms Creek and Crab Orchard Branch watersheds are populated by approximately 2,879 residents living in approximately 1168 households. Of those households, 413 are in Sepulcher Creek drainage, 657 are in the Toms Creek watershed and 98 are in Crab Orchard Branch. Only the lower sections of Toms Creek and Little Toms Creek are served by public sewer. The presence of public sewer is represented on Figure 7 by the small dots. The remaining homes in the watersheds use other methods to handle sewage.

A nonpoint source inventory, generated by Tennessee Valley Authority, for the Guest River Benthic Total Maximum Daily Load Report in 2003 is useful to determine suspicious septic system sites. The inventory uses infrared, low altitude, aerial photography taken in March 2001. Conditions between 1 and 4 were assigned to each site with suspicious septic system characteristics. Condition 1 is the most severe based on visible ponding down gradient of a home. Condition 2 represents sites where photographs depict suspicious moisture patterns with a visible plume pattern but no apparent fieldlines. Condition 3 is for sites with a distinctive drainfield or fieldline pattern but no plume evident. Finally, Condition 4 describes sites that appear suspicious because the location is not conducive to supporting a successful septic system. Reasons that locations may not support septic systems include; homes on very steep slopes, small lots, lots with visible rock outcrops, lots in close proximity to streams or reservoirs, or heavily wooded lots. The table in Figure 6 gives numbers of households with suspicious septic systems.

Results of the nonpoint source inventory show that 9 percent of the households in Sepulcher Creek have failing systems, 16 percent in Toms Creek are failing and 100 percent of homes with septic systems in Crab Orchard Branch watershed may be failing. If Condition 4 homes are eliminated from the failing category, then 2 percent in Sepulcher Creek , 7 percent in Toms Creek and 72 percent in Crab Orchard Branch watershed are failing. Of the 1,303 buildings in the Sepulcher Creek, Toms Creek and Crab Orchard Branch watersheds, about 90 percent are located in non-sewered zones. Figure 8 shows that most of these septic systems are located within 1 mile of the impaired streams.

Figure 7. Sewered and Non-Sewered Areas in the Sepulcher Creek, Toms Creek and Crab Orchard Branch Watersheds

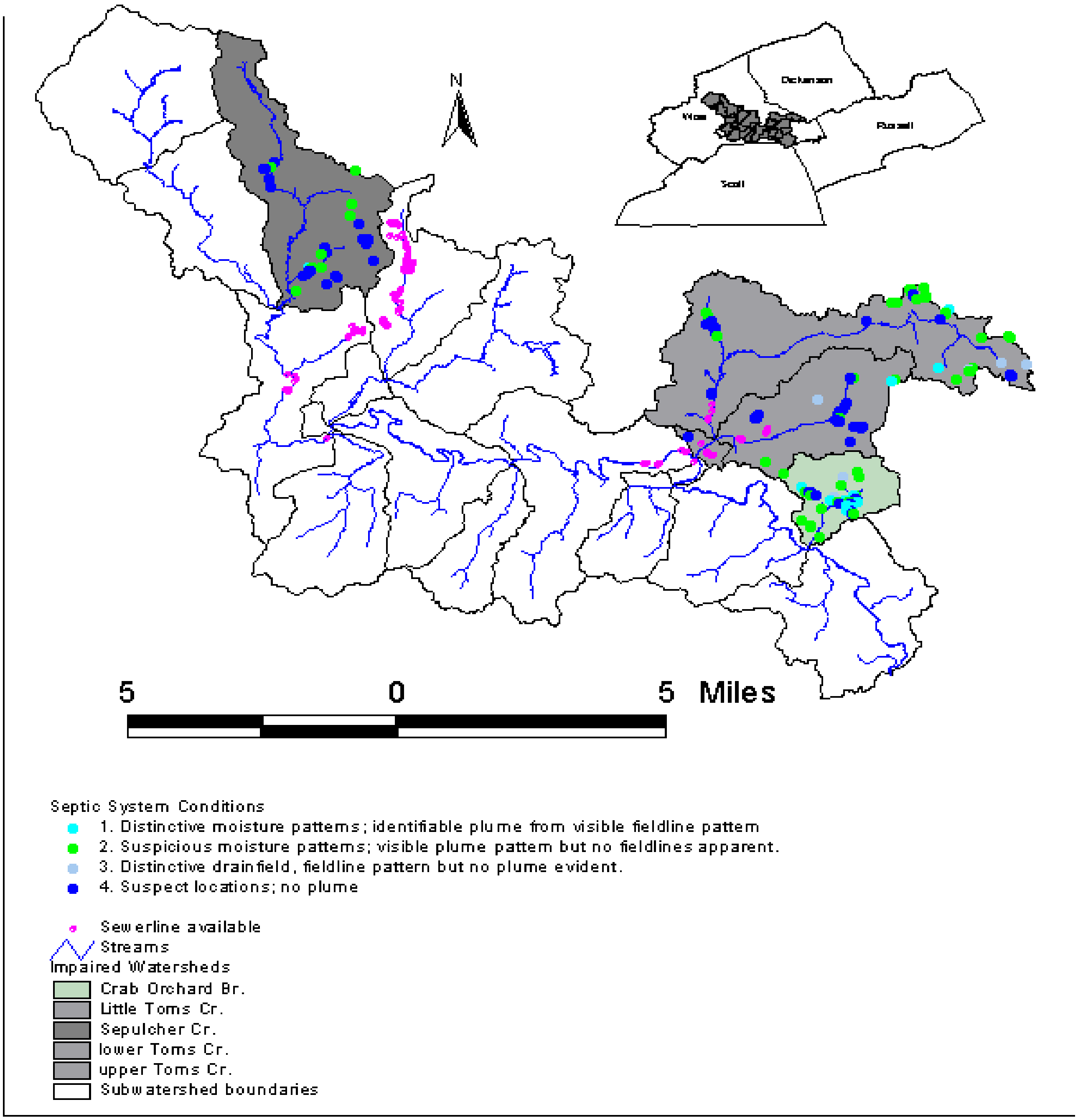
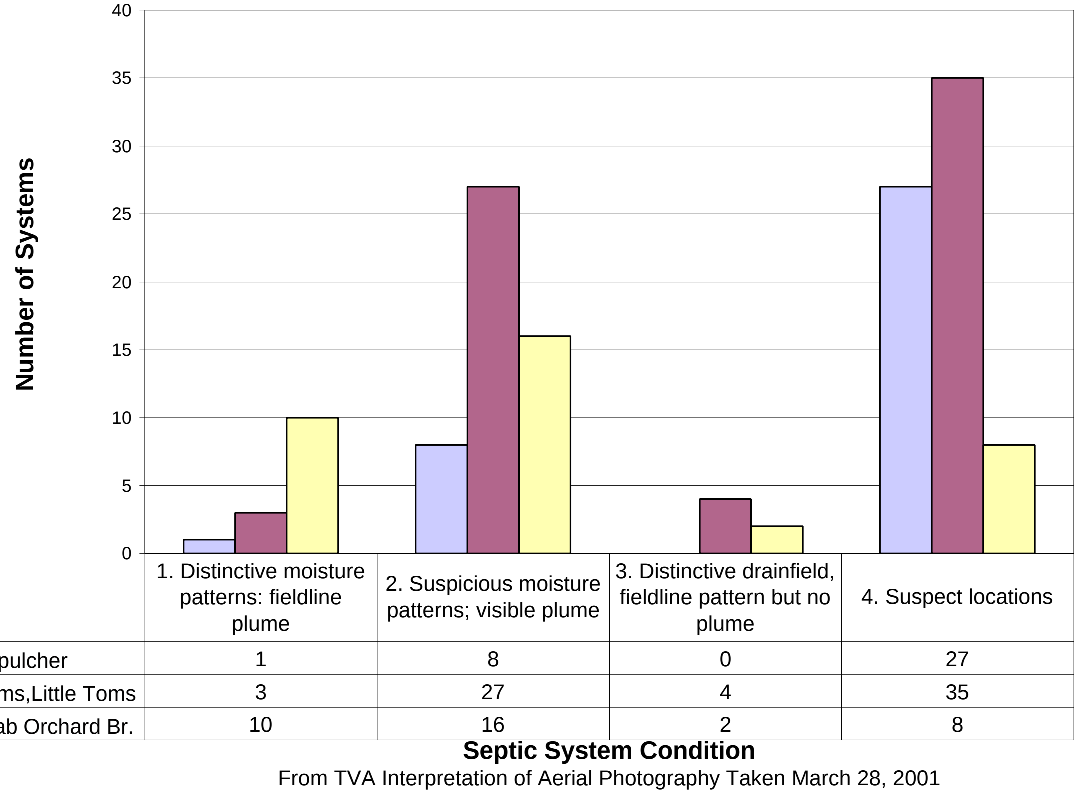


Figure 8. Septic Systems Conditions in Sepulcher Creek, Toms Creek and Crab Orchard Branch Watersheds



	1. Distinctive moisture patterns: fieldline plume	2. Suspicious moisture patterns; visible plume	3. Distinctive drainfield, fieldline pattern but no plume	4. Suspect locations
Sepulcher	1	8	0	27
Toms,Little Toms	3	27	4	35
Crab Orchard Br.	10	16	2	8

Based on the estimated population and number of households, there are an average of 2.5 people per household in the Sepulcher Creek, Toms Creek and Crab Orchard Branch watersheds. Assuming a wastewater production rate of 75 gallons per day per person (Geldreich, 1978), and a fecal coliform density in septic tank waste of 1.04×10^{6} cfu per 100 ml (MapTech, 2002), the total septic load in the Sepulcher Creek watershed is estimated to be 3.05×10^{12} cfu per day. The loading in Toms Creek watershed is estimated to be 5.04×10^{12} cfu per day and the load in Crab Orchard Branch watershed is estimated to be 0.72×10^{12} cfu per day. Of this total septic load, only the load from failing septic systems would be available as runoff. Septic system failure rates depend largely on the age of the septic system. Previous TMDL studies estimated that septic systems in a watershed fail at rates between 5% and 15%.

Biosolids

In the Commonwealth of Virginia, the VDH and the DEQ regulate biosolids generation and application to the land surface. The DEQ regulates the generation of biosolids and the land application of those biosolids by the generator. The VDH regulates contractors who transport and spread biosolids; the biosolids can be from in-state or out-of-state sources.

The DEQ comprehensive environmental database was queried for biosolids application permits in the Sepulcher Creek, Toms Creek and Crab Orchard Branch watershed and two biosolid land applications sites were identified in the Toms Creek Watershed. Coeburn-Norton-Wise Wastewater Treatment Plant applied for approval from DEQ, in November 2002, to land apply biosolids at two sites, Dale Ridge and Rabbit Ridge in the Toms Creek watershed. The application rate on the 184-acre site at Dale Ridge is 92 dry tons per acre and on the 25 acre Rabbit Ridge site it is 44 dry tons per acre during 3 years. Tallgrass hay is the agricultural crop at these locations. Although these biosolid application sites are permitted for C-N-W, the wastewater treatment plant currently presses biosolids and disposes of them at the Wise County Landfill.

Pets

The numbers of pets in the watershed are estimated based on the number of households. Assuming an average of 1.7 dogs and 2.1 cats per household (National Pet Owner Survey, American Pet Products Manufacturers Association, 2001-2002), the estimated pet population in the Sepulcher Creek watershed is 867 cats and 702 dogs. The estimate for Toms Creek watershed is 1380 cats and 1117 dogs. Crab Orchard Branch pet population estimate is 206 cats and 167 dogs. Using the waste production rates and fecal coliform densities from MapTech, 2002, the total bacteria loads from dogs and cats in Sepulcher Creek watershed are 1.52×10^{11} and 1.51×10^{5} cfu per day, respectively. Toms Creek watershed has 2.41×10^{11} cfu/day for dogs and 2.41×10^{5} cfu/day for cats and Crab Orchard Branch has 0.36×10^{11} cfu/day for dogs and 0.36×10^{5} for cats. Tables 13, 14 and 15 present the calculations for human and pet loads in the Sepulcher, Toms Creek and Crab Orchard Branch watersheds. It should be noted that the numbers presented in these tables represent loads available for runoff and not in-stream loads.

Table 13. Fecal coliform loads from septic systems and pets in the Sepulcher Creek watershed

Source	Population	Waste Production Rate	Waste Fecal Coliform Density	Total Fecal Coliform Load (cfu/yr)
Septic Systems	1022	75 gal/day/person x 37.85412 100mL/gal = 2.84×10^{3} 100mL/day/person *	1.04×10^{6} cfu/100mL **	1.11×10^{15}
Dogs	702 dogs	450 g/dog **	4.8×10^{5} cfu/g **	5.54×10^{13}
Cats	867 cats	19.4 g/cat **	9 cfu/g **	5.51×10^{7}

* Geldreich, 1978. A conversion factor of 37.85412 was used to convert gallons to 100mL.

** MapTech, 2002.

Table 14. Fecal coliform loads from septic systems and pets in the Toms Creek watershed

Source	Population	Waste Production Rate	Waste Fecal Coliform Density	Total Fecal Coliform Load (cfu/yr)
Septic Systems	1610	75 gal/day/person x 37.85412 100mL/gal = 2.84×10^{3} 100mL/day/person *	1.04×10^{6} cfu/100mL **	1.62×10^{15}
Dogs	1117 dogs	450 g/dog **	4.8×10^{5} cfu/g **	8.79×10^{13}
Cats	1380 cats	19.4 g/cat **	9 cfu/g **	8.80×10^{7}

* Geldreich, 1978. A conversion factor of 37.85412 was used to convert gallons to 100mL.

** MapTech, 2002.

Table 15. Fecal coliform loads from septic systems and pets in the Crab Orchard Branch watershed

Source	Population	Waste Production Rate	Waste Fecal Coliform Density	Total Fecal Coliform Load (cfu/yr)
Septic Systems	247	75 gal/day/person x 37.85412 100mL/gal = 2.84×10^3 100mL/day/person *	1.04×10^6 cfu/100mL **	2.63×10^{14}
Dogs	167 dogs	450 g/dog **	4.8×10^5 cfu/g **	1.31×10^{13}
Cats	206 cats	19.4 g/cat **	9 cfu/g **	1.31×10^7

* Geldreich, 1978. A conversion factor of 37.85412 was used to convert gallons to 100mL.

** MapTech, 2002.

5.3.2. Livestock

Fecal matter from livestock can be deposited directly to the stream in instances where livestock have stream access, or the fecal matter can be transported to the stream in surface runoff from grazing or pasture lands. It should be noted that the numbers presented in these tables represent loads available for runoff and not in-stream loads.

The predominant types of livestock in the Sepulcher Creek, Toms Creek and Crab Orchard Branch watershed are cattle and horses, although all types of livestock were considered in developing the TMDL. The Tennessee Valley Authority IPSI Report for the Guest River Benthic Total Maximum Daily Load Report data was used to estimate the livestock population in the watershed. Table 16 presents the livestock population estimates, fecal coliform production rates, and fecal coliform loads in the watersheds.

Table 16. Fecal coliform loads from livestock in the Sepulcher Creek, Toms Creek and Crab Orchard Branch watershed

Watershed	Population*		Waste Production Rate** (lbs/animal/day)	Waste Fecal Coliform Density** (cfu/g)	Total Fecal Coliform Load*** (cfu/yr)
	Source	Estimated Number of Animals			
Sepulcher Creek	Beef Cows	50	46.4	1.01×10^5	3.90×10^{13}
	Horses	1	51.0	9.40×10^4	7.92×10^{11}
Toms Creek	Beef Cows	210	46.4	1.01×10^5	1.63×10^{14}
	Horses	5	51.0	9.40×10^4	3.98×10^{12}
Crab Orchard Br.	Beef Cows	30	46.4	1.01×10^5	2.34×10^{13}
	Horses	1	51.0	9.40×10^4	7.92×10^{11}

* The livestock population in the Sepulcher Creek, Toms Creek and Crab Orchard Branch watershed was estimated from the TVA IPSI report.

** MapTech, 2002.

*** A conversion factor of 453.6 was used to convert pounds to grams.

5.3.3. Wildlife

Like livestock, fecal matter from wildlife can be either deposited directly to the stream, or it can be transported to the stream in surface runoff from woods, pastureland and cropland. Direct deposition to streams varies with species, e.g. beaver spend most of their time in water; therefore most of their fecal matter would be directly deposited to the stream. It should be noted that the numbers presented in these tables represent loads available for runoff and not in-stream loads.

Wildlife populations in the Sepulcher Creek, Toms Creek and Crab Orchard Branch watershed were estimated based on wildlife densities compiled by Virginia Department of Conservation and Recreation in 2003. The acreage and miles of habitat are derived from the Guest River IPSI report in the Guest River Benthic TMDL Report. Land use data from the IPSI report included reclaimed strip mine and abandoned strip mine acreage that was lumped into the forest use for purposes of estimating the wildlife numbers. Habitat was assigned as follows:

- deer: deciduous forest, evergreen forest, mixed forest, woody wetlands
- turkey: deciduous forest, evergreen forest, mixed forest
- muskrat: woody wetlands, emergent herbaceous wetlands, open water
- beaver: stream miles
- raccoon: low intensity residential, deciduous forest, evergreen forest, mixed forest, woody wetlands
- goose: pasture/hay, row crops, emergent herbaceous wetlands, open water
- mallard: woody wetlands, emergent herbaceous wetlands, open water

Table 17. Fecal coliform loads from wildlife in the Sepulcher Creek watershed

Source	Population Density*	Habitat**	Watershed Population (animals)	Range of Waste Production Rate* (cfu/an/day)		Range of Waste Fecal Production (cfu/yr)	
				Low	High	Low	High
Deer	0.084 an/ac	4,716.8 ac	396	1.52×10^8	3.6×10^8	2.20×10^{13}	5.21×10^{13}
Turkey	0.010 an/ac	3,422.3 ac	34	9.3×10^7		1.16×10^{12}	
Muskrat	2.751 an/ac	221.3ac	609	2.5×10^7	1.9×10^8	5.55×10^{12}	4.23×10^{13}
Beaver	4.800 an/mi	10.1 mi	15	3.00×10^6		1.61×10^{10}	
Raccoon	0.070 an/ac	5,127.8 ac	359	2.05×10^7	9.45×10^8	2.69×10^{12}	1.24×10^{14}
Goose	0.004 an/ac	395.1 ac	2	5.87×10^4	2.25×10^9	3.39×10^7	1.30×10^{12}
Mallard	0.002 an/ac	221.3 ac	1	2.43×10^9		3.94×10^{11}	

- *VADCR, 2003.
- **TVA IPSI, 2003.

Table 18. Fecal coliform loads from wildlife in the Toms Creek watershed

Source	Population Density*	Habitat**	Watershed Population (animals)	Range of Waste Production Rate* (cfu/an/day)		Range of Waste Fecal Production (cfu/day)	
				Low	High	Low	High
Deer	0.084 an/ac	7,777.2 ac	653	1.52×10^8	3.6×10^8	3.62×10^{13}	8.58×10^{13}
Turkey	0.010 an/ac	7,714.1 ac	77	9.3×10^7		2.62×10^{12}	
Muskrat	2.751 an/ac	91.8 ac	253	2.5×10^7	1.9×10^8	2.30×10^{12}	1.75×10^{13}
Beaver	4.800 an/mi	17.4 mi	83	3.00×10^6		9.14×10^{10}	
Raccoon	0.070 an/ac	8,913.8 ac	624	2.05×10^7	9.45×10^8	4.67×10^{12}	2.14×10^{14}
Goose	0.004 an/ac	767.8 ac	3	5.87×10^4	2.25×10^9	6.58×10^7	2.52×10^{12}
Mallard	0.002 an/ac	91.8 ac	1	2.43×10^9		1.63×10^{11}	

- *VADCR, 2003.
- **TVA IPSI, 2003.

Table 19. Fecal coliform loads from wildlife in the Crab Orchard Branch watershed

Source	Population Density*	Habitat**	Watershed Population (animals)	Range of Waste Production Rate* (cfu/an/day)		Range of Waste Fecal Production (cfu/yr)	
				Low	High	Low	High
Deer	0.084 an/ac	1,306.9 ac	110	1.52×10^{8}	3.6×10^{8}	6.09×10^{12}	1.44×10^{13}
Turkey	0.010 an/ac	1,300.7 ac	13	9.3×10^{7}		4.42×10^{11}	
Muskrat	2.751 an/ac	7.9 ac	22	2.5×10^{7}	1.9×10^{8}	1.98×10^{11}	1.51×10^{12}
Beaver	4.800 an/mi	3.1 mi	15	3.00×10^{6}		1.61×10^{10}	
Raccoon	0.070 an/ac	1,591.8 ac	111	2.05×10^{7}	9.45×10^{8}	8.34×10^{11}	3.84×10^{13}
Goose	0.004 an/ac	114.4 ac	0.5	5.87×10^{4}	2.25×10^{9}	9.80×10^{6}	3.76×10^{11}
Mallard	0.002 an/ac	7.9 ac	0.1	2.43×10^{9}		1.40×10^{10}	

- *VADCR, 2003.
- **TVA IPSI, 2003.

6. TMDL Development

One of the major obstacles to improving stream water quality is that the potential sources of bacteria are numerous and the dominant sources and/or pathways are generally unknown. This can make it difficult to direct effective cleanup efforts.

Typical pathogen TMDLs are completed by developing watershed-based computer simulations that establish links between sources and in-stream water quality. While effective, the effort required to develop modeled TMDLs can be costly. In an effort to complete pathogen TMDLs in a timely and cost-effective manner, the use of load-duration analyses has been investigated. It has been determined that the load-duration method of calculating a TMDL produces a result only slightly more conservative than if the TMDL had been determined through computer modeling.

The load duration method essentially uses an entire stream flow record to provide insight into the flow conditions under which exceedances of the water quality standard occur. Exceedances that occur under low flow conditions are generally attributed to loads delivered directly to the stream such as straight pipes and livestock with access to the stream. Exceedances that occur under high flow conditions are typically attributed to loads that are delivered to the stream in stormwater runoff. Exceedances occurring under during normal flows can be attributed to a combination of runoff and direct deposits.

The following sections detail the development of the load-duration TMDL and associated allocations.

6.1. Load-Duration Curve

Development of a load-duration curve begins with a flow-duration curve, and in order to develop a meaningful flow-duration curve one must have several years of flow data for the target stream or river. Where very little flow data exists for a target stream, a reference stream with the requisite flow measurements must be used similar to the paired watershed approach used in watershed-based modeling. In the case of Sepulcher Creek, Toms Creek and Crab Orchard Branch, the United State Geological Survey (USGS) and DEQ operate a stream gage on Clinch River that was used to develop the flow duration curve.

The following sections detail the flow data, the development of a flow-duration and the creation of a load-duration curve for Sepulcher Creek, Toms Creek and Crab Orchard Branch.

6.1.1. Flow Data

The USGS stream gage #3524000 has operated since 1920 with over 80 years of published data, from October 1, 1920 to September 30, 2002. Daily provisional flow data is available from October 1, 2002 until November 1, 2003. Daily average flow measurements were available. This stream gage is located in Cleveland, Virginia.

6.1.2. Flow-Duration Curves

There is a paucity of flow data for each of the streams due to their relative small size. Consequently, the Department of Environmental Quality undertook special studies at the mouths of each stream to augment as well as validate the use of reference stream information for generating flows. Flow measurements were taken within each impaired segment from late 2002 to early 2003.

The measurement data from the stream gauges were entered into Excel spreadsheets along with daily mean flow data from nearby, long-term, continuous record gauging stations. Using Excel’s “Regression” data analysis tool, the impaired streams gauge data (dependent variable) were correlated against data sets from several long-term gauging stations (independent variable). The long-term gauge data that produced a high correlation coefficient and had comparable topography and watershed characteristics were selected and used to predict the flow patterns for the impaired watershed streams. For this analysis, Clinch River near Cleveland, Virginia (#3524000) was selected as the long-term reference station.

Using the Excel graphing package, the measurement data from the impaired stream gauges were plotted against the corresponding daily mean flow data for the Clinch River gauge. Then, a best-fit line through the data points and the equation for the "regression" line were developed in Excel. Using the equation for the regression line, a daily mean flow value from the long-term continuous record gauge could be plugged into the "x" or independent variable in the equation and the flow at the impaired stream gauge, the "y" or dependent variable, could be calculated. Figures 9, 11, and 13, below, represent the linear regression graphs for each of the impaired watersheds.

In order to use the "Flow Duration" method to develop the TMDL, a flow duration curve must be developed for the impaired stream. This is accomplished by first developing a flow duration curve for the representative long-term gauge. A flow duration curve is simply a Log/Log plot showing the flow magnitude (cfs) along the "y" or vertical axis and the frequency of daily average stream flow (%) along the "x" or horizontal axis. For example, the flow value corresponding to "1%" is the flow that is exceeded only 1% of the time for which measurements exist. Likewise, the flow value corresponding to "30%" is the flow that 30% of the historic record flows exceed.

The flow values used in the "Flow Duration" plot for impaired streams, Sepulcher Creek, Toms Creek and Crab Orchard Branch, were determined using the "Percentile" function in Excel. Each percentile was entered into the function equation along with the coordinates that defined the range of the daily mean data set. The resulting flow values were plotted (Log/Log) against the percentiles and a curve was drawn through the data points. The flows corresponding with the percentiles were then plugged into the regression equation and a new set of flows was generated for the impaired streams. These generated flows are plotted against the same percentiles and the "Flow Duration" curve is represented in Figures 10, 12 and 14.

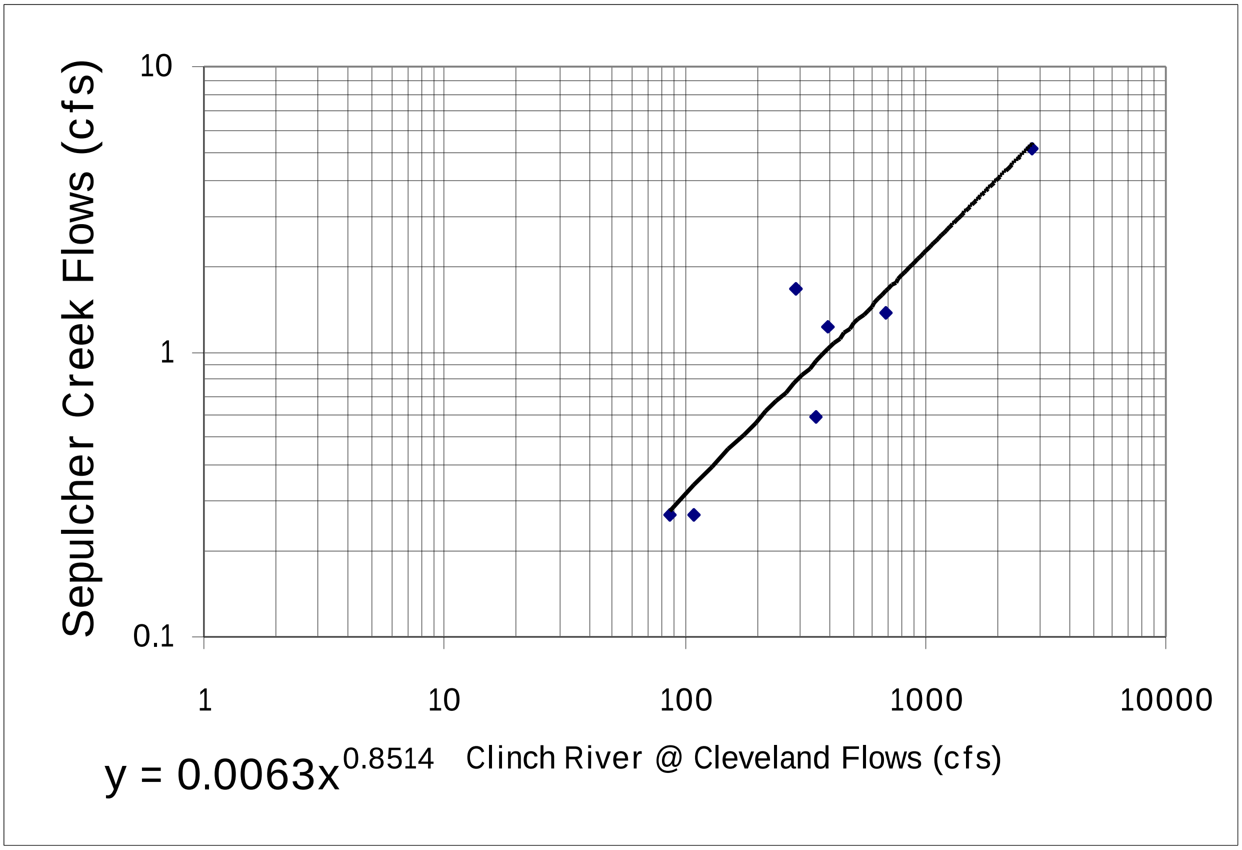
Sepulcher Creek

Sepulcher Creek watershed is near the headwaters of Guest River. One of the main tributaries to Sepulcher Creek is Rocky Fork which flows almost due south to confluence with Sepulcher Creek about half-mile from its mouth. The watershed is located in Wise County, to the south and west of the Town of Wise Virginia. It has a drainage area of about 9 square miles. It is a tributary to the Guest River and flows south to confluence with Guest River.

The surface water hydrology of the Sepulcher Creek watershed was determined based on data collection at a special study site (#3524307.5). Site specific flow measurements were collected by the Virginia Department of Environmental Quality from late 2002 to early 2003. The measurements are within the limits of the impaired segment, at the Railroad crossing, approximately 0.5 miles upstream from the mouth. The average flow for Sepulcher Creek is 1.52 cubic feet per second.

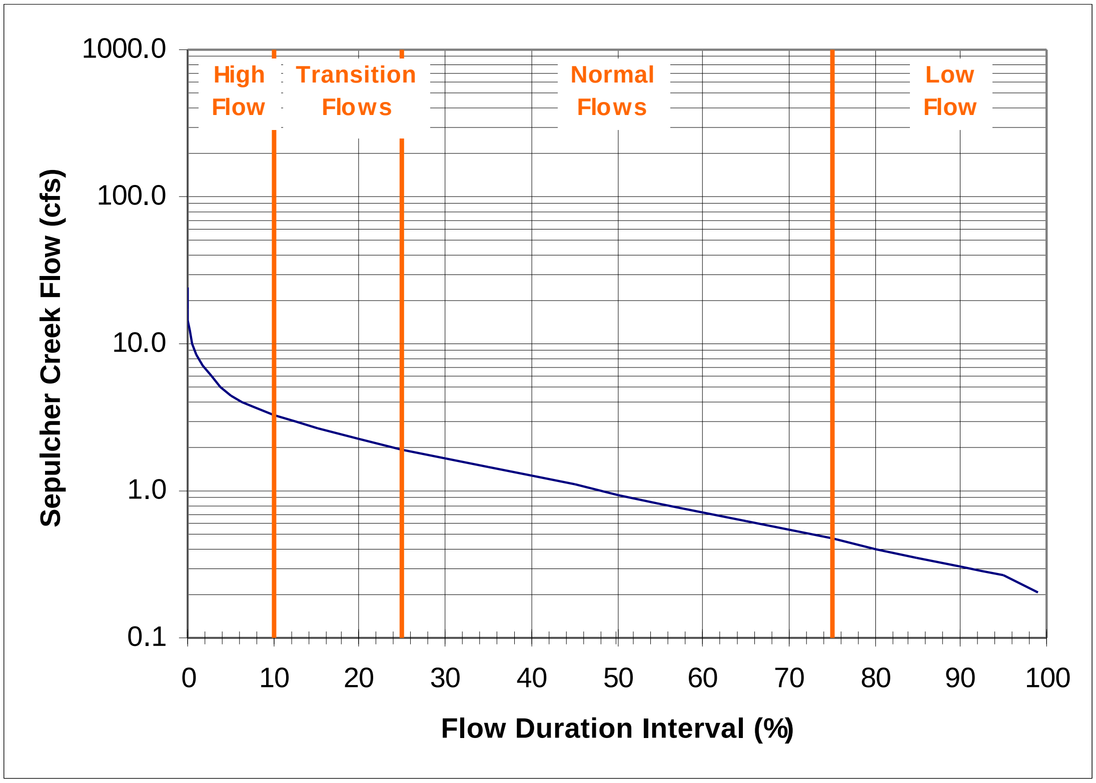
Flows for Sepulcher Creek were correlated with those for Clinch River. Figure 9 represents the flow regression graph.

Figure 9. Flow Regression for Sepulcher Creek and Clinch River (#3524000)



The flow-duration curve for Sepulcher Creek has been divided into four sections to help illustrate flow conditions. These sections are titled "High Flows", "Transition Flows", "Normal Flows", and "Low Flows". Low flows can be roughly equated to near-drought or drought flows. High flows are near-flood or flood flows. Transition flows are, as implied, neither normal nor high. In the graph below (Figure 10), a 75% flow duration interval corresponds to a flow of 0.5 cfs, or 75% of the time the flow in Sepulcher Creek is greater than 0.5 cfs.

Figure 10. Flow duration curve for Sepulcher Creek



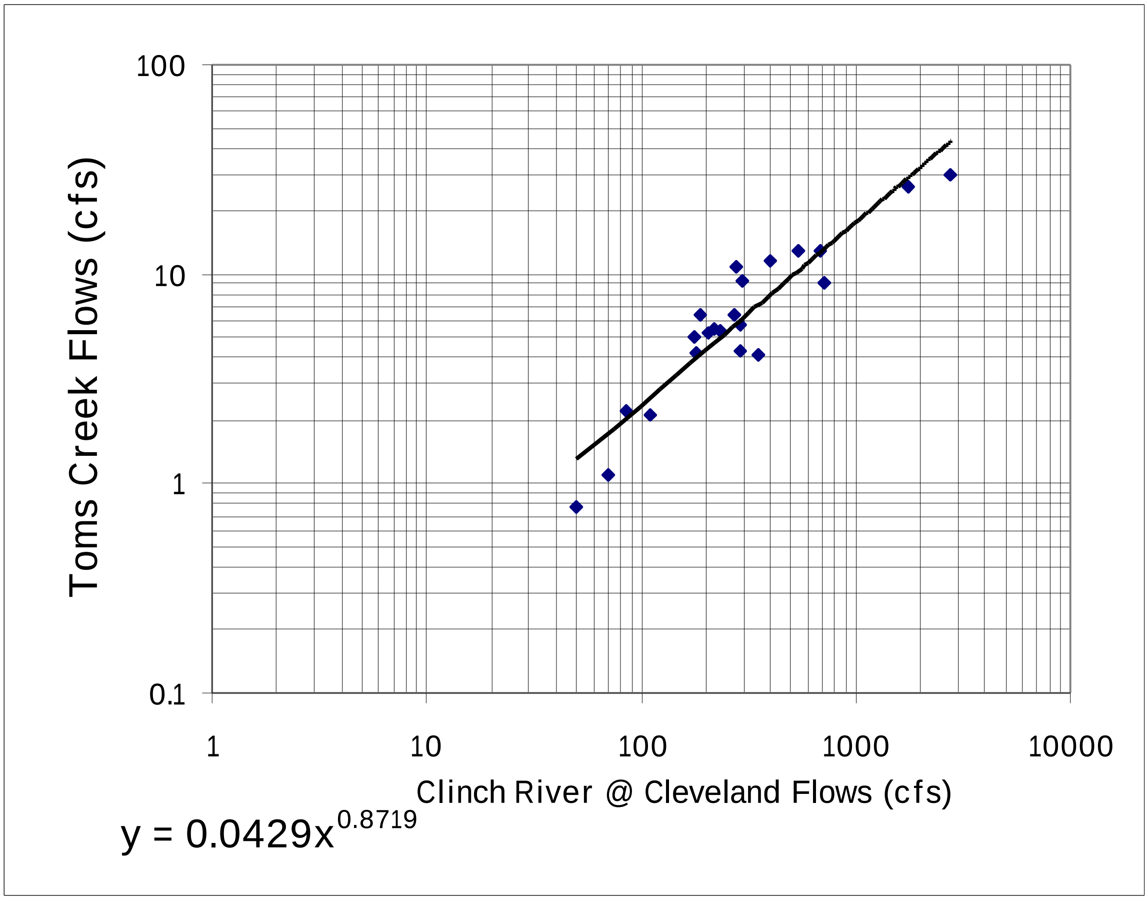
Toms Creek

The confluence between Toms Creek watershed and Guest River occurs half way between the headwaters of Guest River and the mouth of Guest River. One of the main tributaries to Toms Creek is Little Toms Creek. Both streams flow through the Town of Coeburn, Virginia. Confluence between Little Toms Creek and Toms Creek is within Coeburn town limits. The watershed is located in Wise County, to the north and within the Town of Coeburn, Virginia. Toms Creek has a drainage area of about 16 square miles, 11 square miles in Toms Creek drainage and over 5 square miles in Little Toms Creek. Toms Creek is a tributary to the Guest River and flows south and east to its confluence with Guest River.

The surface water hydrology of the Toms Creek watershed was determined based on a special study site (#3524445). Site specific flow measurements were collected by the Virginia Department of Environmental Quality from late 2002 to early 2003. The measurements are within the limits of the impaired segment, approximately 0.6 mile upstream of the mouth. The average flow for Toms Creek is 12.21 cubic feet per second.

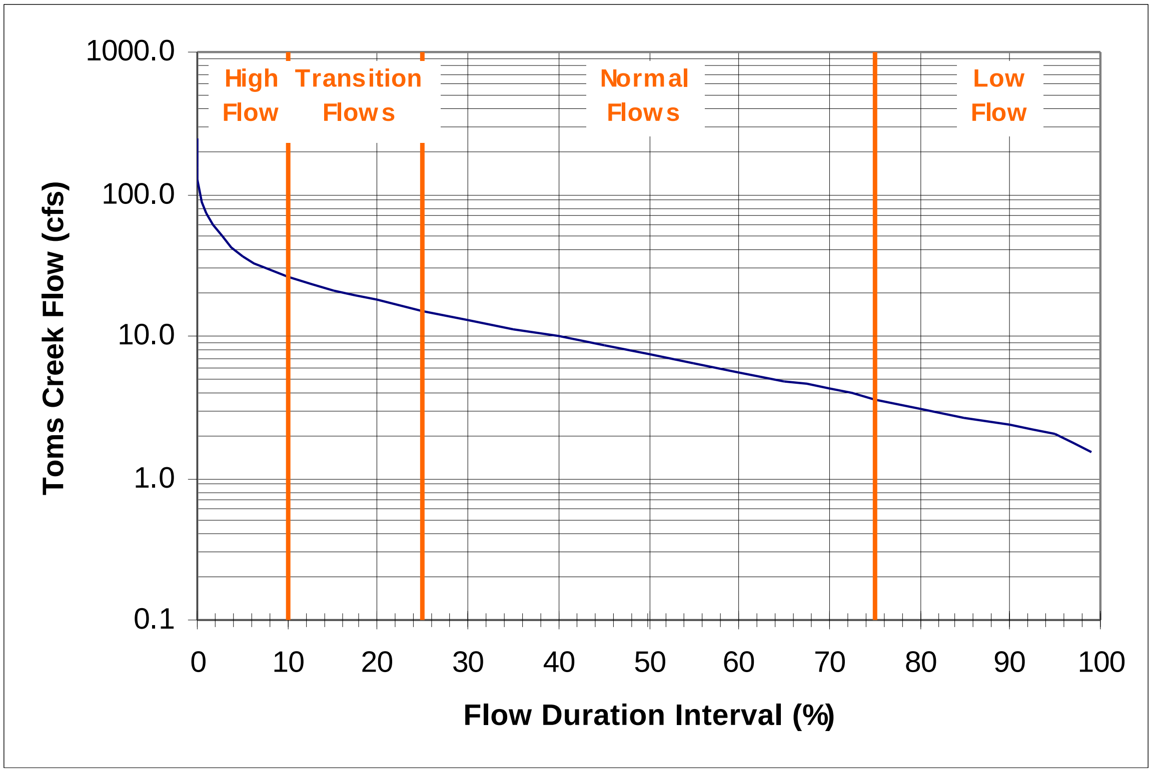
Figure 11 represents the flow regression correlation between Clinch River and Toms Creek.

Figure 11. Flow Regression for Toms Creek and Clinch River (#3524000)



The flow-duration curve for Toms Creek has been divided into four sections to help illustrate flow conditions. These sections are titled "High Flows", "Transition Flows", "Normal Flows", and "Low Flows". Low flows can be roughly equated to near-drought or drought flows. High flows are near-flood or flood flows. Transition flows are, as implied, neither normal nor high. In the graph below (Figure 12), a 75% flow duration interval corresponds to a flow of 3.6 cfs, or 75% of the time the flow in Toms Creek is greater than 3.6 cfs.

Figure 12. Flow Duration Curve for Toms Creek



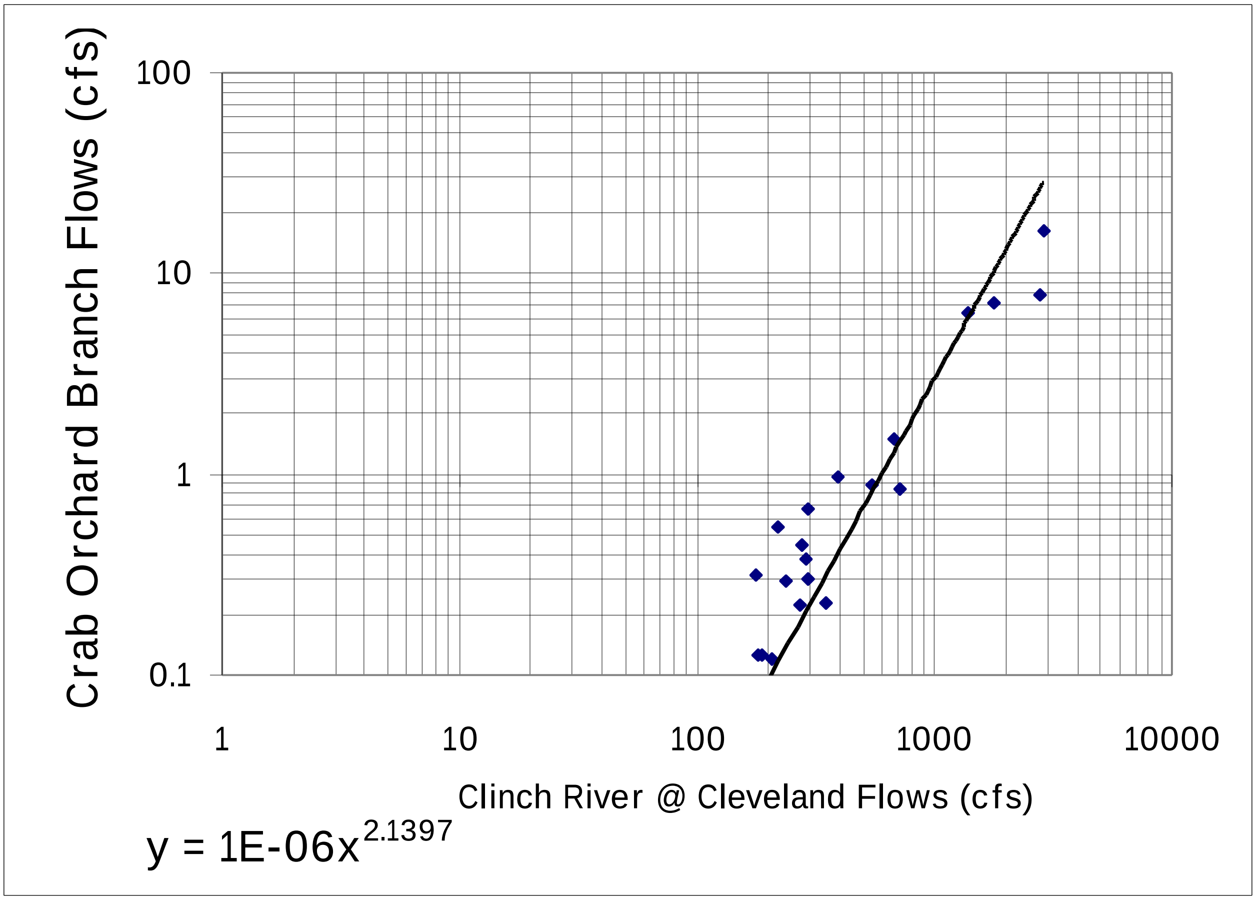
Crab Orchard Branch

Crab Orchard Branch watershed is the smallest of the impaired watersheds. It is located below Coeburn. The watershed is located in Wise County, between Coeburn Virginia and Clinch River. It has a drainage area of about 2.7 square miles. It is a tributary to the Guest River and flows south to confluence with Guest River.

The surface water hydrology of the Crab Orchard Branch watershed was determined based on a special study site (#3524520). Site specific flow measurements were collected by the Virginia Department of Environmental Quality from late 2002 to early 2003. The measurements are within the limits of the impaired segment, at river mile 0.31 or 0.3 miles upstream of its confluence with Guest River. The average flow for Crab Orchard Branch is 4.76 cubic feet per second.

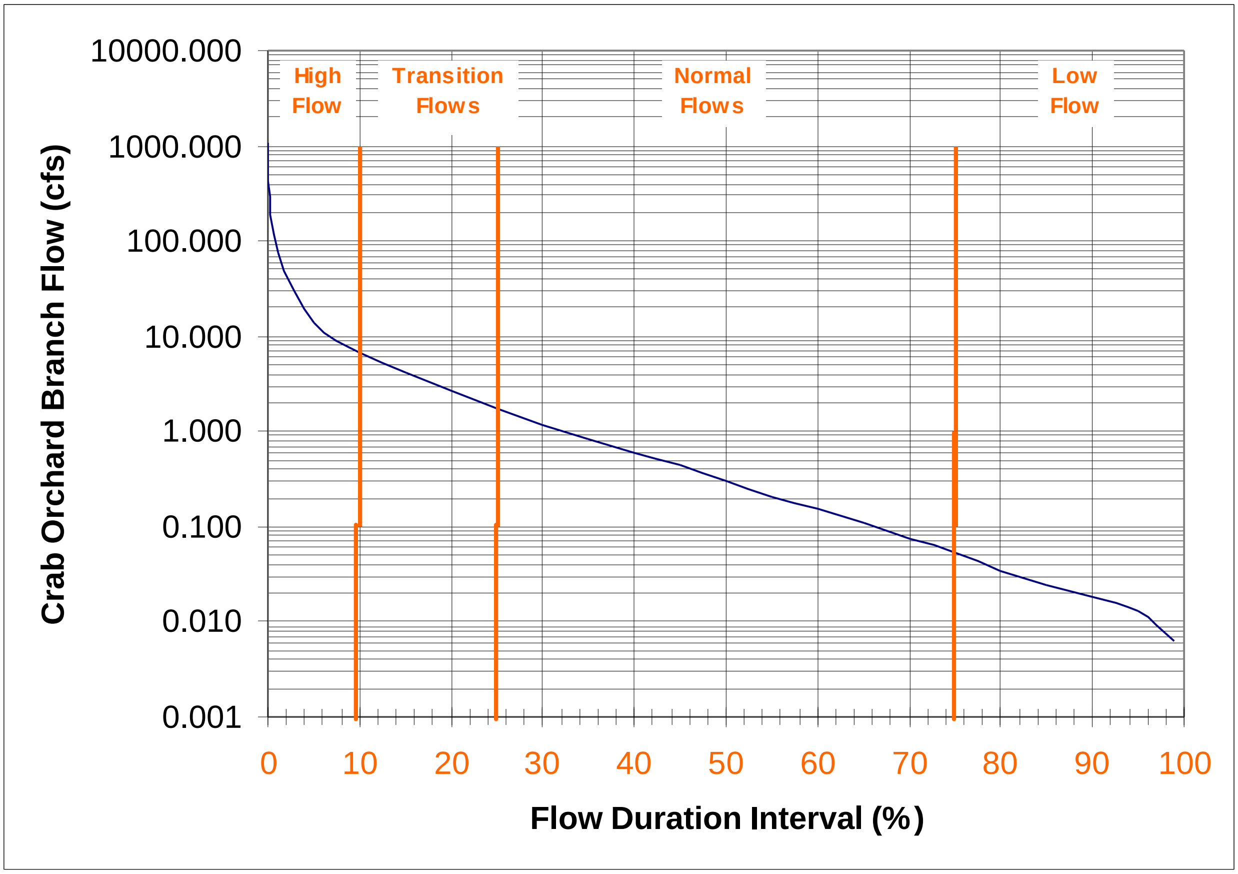
Figure 13 presents the flow regression analysis graph between Crab Orchard Branch and Clinch River.

Figure 13. Flow Regression for Crab Orchard Branch and Clinch River (#3524000)



The flow-duration curve for Crab Orchard Branch has been divided into four sections to help illustrate flow conditions. These sections are titled "High Flows", "Transition Flows", "Normal Flows", and "Low Flows". Low flows can be roughly equated to near-drought or drought flows. High flows are near-flood or flood flows. Transition flows are, as implied, neither normal nor high. In the graph below (Figure 14), a 75% flow duration interval corresponds to a flow of 0.1 cfs, or 75% of the time the flow in Crab Orchard Branch is greater than 0.1 cfs.

Figure 14. Flow duration curve for Crab Orchard Branch



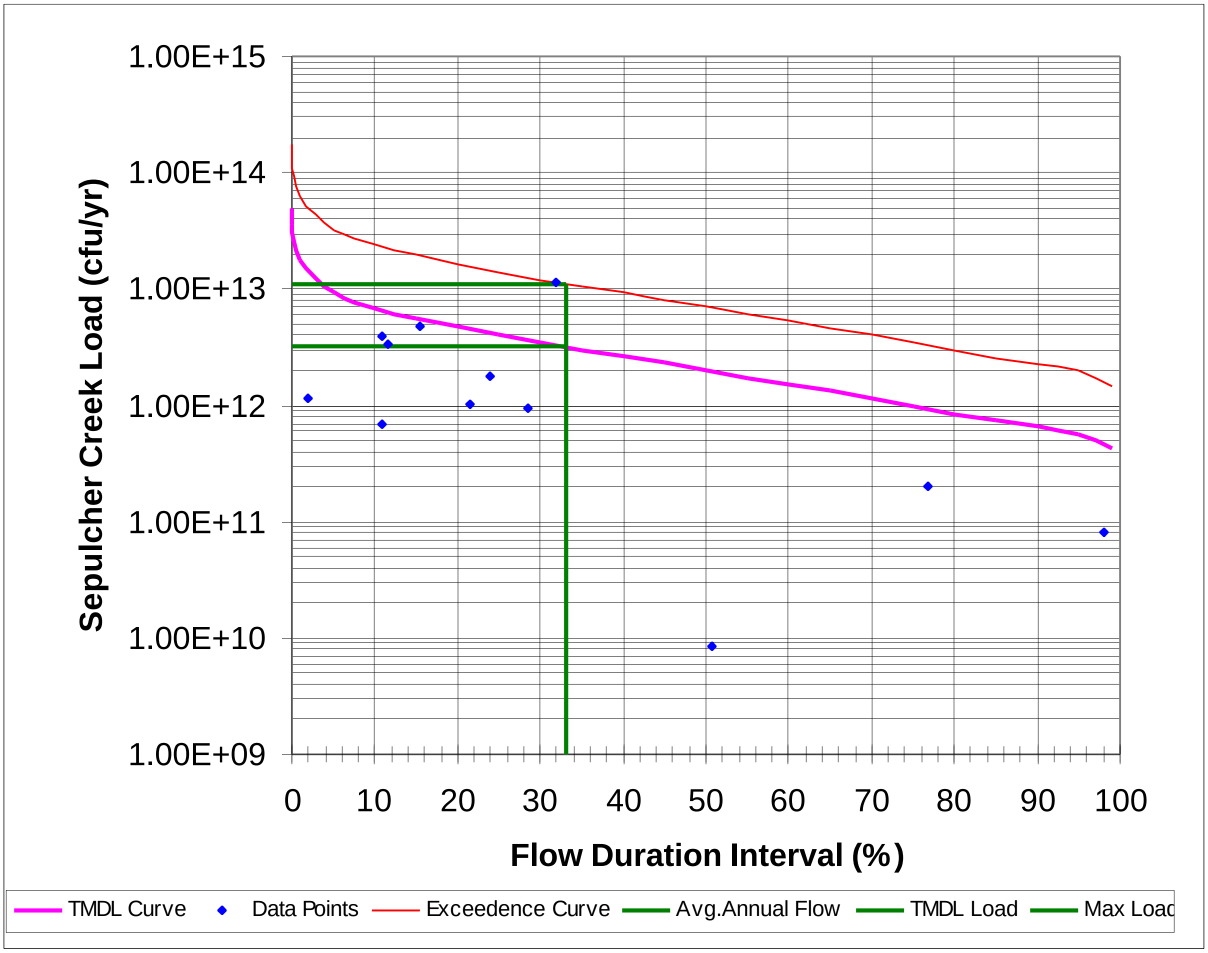
6.1.3. Load-Duration Curve

As mentioned in Section 1.3, the instream water quality observations on Sepulcher Creek, Toms Creek and Crab Orchard Branch were collected near the mouth of each stream. Special flow studies were conducted at the same locations as the water quality data were collected. Consequently, these stations will be the focus of the load duration analysis on each watershed.

A load duration curve is developed by multiplying each flow level along the flow duration curve by the applicable water quality standard. This curve represents the maximum allowable load at each flow level, in other words, the TMDL. Each water quality observation is then assigned to a flow level by comparing the flow record and the date of each observation, and an associated observed load is calculated. By plotting these observed loads on the load duration curve, the number and pattern of exceedances of the water quality standard can be analyzed. The load duration curve and observed data for Sepulcher Creek, Toms Creek and Crab Orchard Branch are shown in Figures 15, 16 and 17. A TMDL line has been plotted for the current E.coli instantaneous standard of 235 cfu/100mL.

Sepulcher Creek

Figure 15. Load duration curve, observed data and maximum exceedance curve for Sepulcher Creek at station 6BSEP000.55

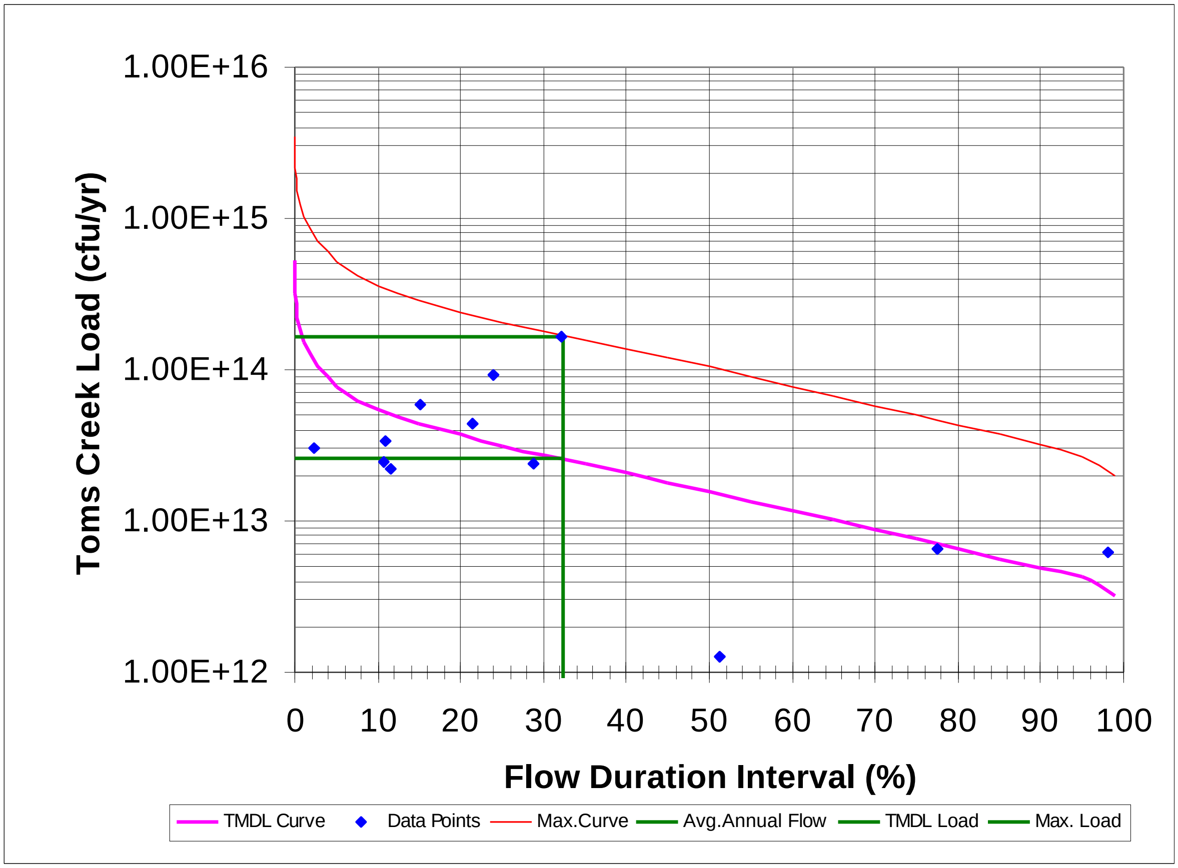


In order to determine the necessary load reduction at the average annual flow condition, a second curve must be drawn through the highest exceedence. The second curve represents the magnitude of the highest observed exceedence if it were to occur over any flow condition.

The graph of the load-duration curve with the max-exceedance curve is presented in Figure 15. The lower curve represents the E.coli. water quality standard under all flow conditions. The data points above the lower curve represent violations of the water quality standard. Since this violation occurs under normal flow, this data point suggests that exceedances of the water quality standard occur under normal flow conditions. Under normal flow conditions, it is likely that direct deposit nonpoint sources and traditional nonpoint sources both contribute to the impairment. The highest exceedance of the water quality standard occurs at a flow that is exceeded 32% of the time. This represents the critical condition and the flow under which the largest reduction is required to meet water quality standards. The observed load at the critical condition is 11.5 x 10^{12} cfu/100mL. Under the current standard of 235 cfu/100mL, this load would have to be reduced by 71% to 3.30 x 10^{12} cfu/100mL. The allowable load is simply the *E. coli* standard multiplied by the applicable flow condition and the proper unit conversions. The full calculation with unit conversions is presented in Appendix C.

Toms Creek

Figure 16. Load duration curve, observed data and maximum exceedence curve for Toms Creek at station 6BTMS000.06

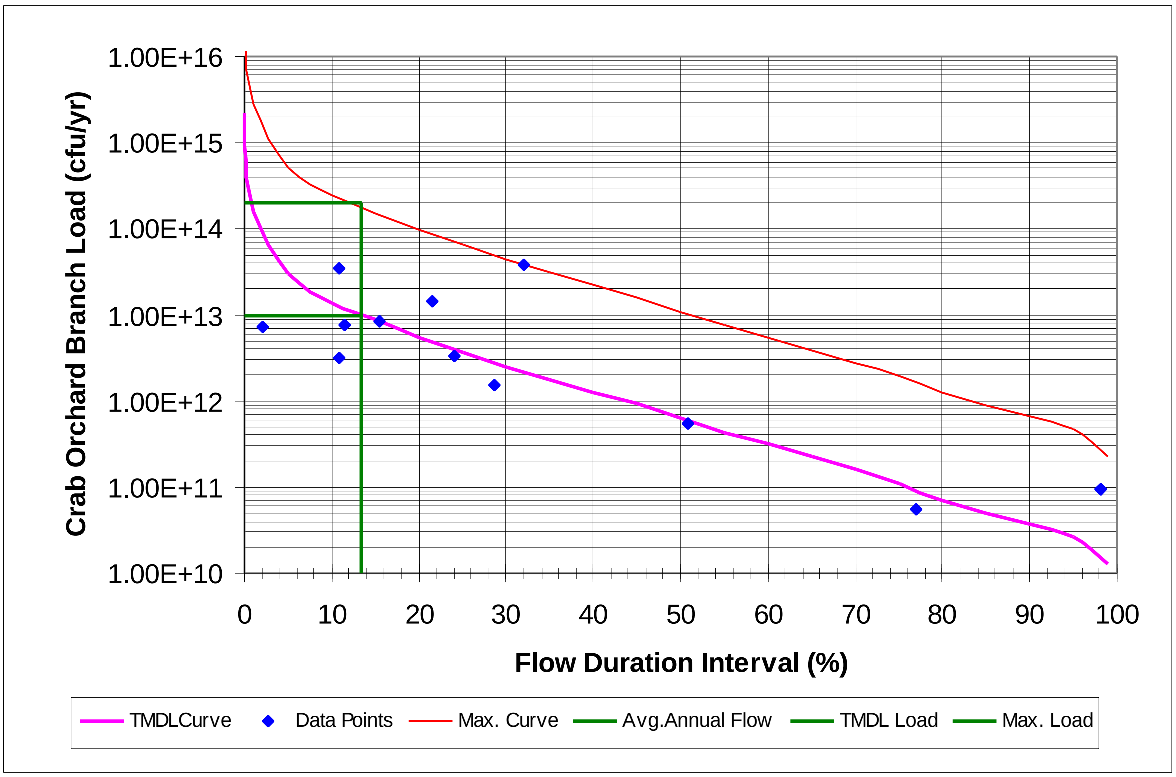


The graph of the load-duration curve for Toms Creek with the max-exceedance curve is presented in Figure 16. The lower curve represents the E.coli. water quality standard under all flow conditions. The data points above the lower curve represent violations of the water quality standard. Since violations occur under low and high flows, it is likely that both to direct deposit nonpoint sources and traditional nonpoint sources are contributing to the impairment. The highest exceedance of the water quality standard occurs at a flow that has been exceeded approximately 31% of the time. This represents the flow condition under which the largest bacteria reduction is required in order to meet water quality standards. The E. coli load at this flow condition is 13.8 x 10^{14} cfu/yr. Under the instantaneous *E. coli* standard of 235 cfu/100mL, this load would have to be reduced by 84% to an allowable load of 2.56 x 10^{13} cfu/yr. The allowable load is simply the *E. coli* standard multiplied by the applicable flow condition and the proper unit conversions. The full calculation with unit conversions is presented in Appendix C.

Crab Orchard Branch

The graph of the load-duration curve for Crab Orchard Branch with the max-exceedance curve is presented in Figure 17. The lower curve represents the E.coli. water quality standard under all flow conditions. The data points above the lower curve represent violations of the water quality standard. Since violations occur under low and high flows, it is likely that direct deposit nonpoint sources and traditional nonpoint sources both contribute to the impairment. The highest exceedance of the water quality standard occurs at a flow that has been exceeded approximately 32% of the time. This represents the flow condition under which the largest bacteria reduction is required in order to meet water quality standards. The E. coli load at this flow condition is 3.89×10^{13} cfu/yr. Under the instantaneous *E. coli* standard of 235 cfu/100mL, this load would have to be reduced by 94% to an allowable load of 2.23×10^{12} cfu/yr. The allowable load is simply the *E. coli* standard multiplied by the applicable flow condition and the proper unit conversions. The full calculation with unit conversions is presented in Appendix C.

Figure 17. Load duration curve, observed data and maximum exceedence curve for Crab Orchard Branch at station 6BCRA000.31



6.2. TMDL

A Total Maximum Daily Load (TMDL) consists of 1) point source/waste load allocations (WLAs), 2) non-point sources/load allocations (LAs) where the non-point sources include natural/background levels, and 3) a margin of safety (MOS) where the margin of safety may be implicitly or explicitly defined. This TMDL definition is typically illustrated by the following equation:

$$TMDL = WLAs + LAs + MOS$$

Simply put, a TMDL is the amount of a pollutant that can be present in a waterbody where the waterbody will still meet water quality standards for that pollutant. In the case of load-duration bacteria TMDLs, the TMDL is expressed as the total number of colony forming units (cfu) per year as opposed to cfu/day. This is because the load-duration TMDL must be based on the average annual flow condition.

The average annual flow for the Sepulcher Creek, Toms Creek and Crab Orchard Branch is calculated from the average annual flow from the USGS steam gage (#3524000). The estimated average annual flow for Sepulcher Creek, Toms Creek and Crab Orchard Branch are 1.52, 12.21 and 4.76 cfs respectively. These flow values have an associated flow duration of 33%, 32% and 13% respectively. From this information an average annual *E. coli* load and TMDL can be calculated from the max-exceedance and TMDL curves. This is represented graphically in Figures 15, 16 and 17. The full calculation is presented in Appendix C.

Sepulcher Creek has an average annual *E. coli* load of 1.11×10^{12} cfu/yr., and the TMDL under average annual flow conditions is 3.19×10^{12} cfu/yr. Toms Creek has an average annual E. coli load of 1.64×10^{14} cfu/yr., and the TMDL under average annual flow conditions is 2.56×10^{13} cfu/yr. Crab Orchard Branch has an average annual E. coli load of 1.74×10^{14} cfu/yr., and the TMDL under average annual flow conditions is 0.998×10^{13} cfu/yr. These values are used to calculate required reductions. By subtracting the waste load allocation (known value) from the TMDL (as determined above), the load allocation can be determined. These values for each watershed are presented in Table 20. Appendix C includes an additional TMDL table for future growth which takes into account the existing permit loadings increased by five fold. The wasteload allocation for Toms Creek is still much less than 1% of the TMDL load at five times of its existing loading. Sepulcher Creek wasteload allocation is 2% of the TMDL at a five fold increase.

Table 20. Average annual *E. coli* loads and TMDL for Sepulcher Creek, Toms Creek including Little Toms, Little Toms Creek and Crab Orchard Branch watershed (cfu/yr.)

	WLA[1]	**LA**	**MOS**	**TMDL**
Sepulcher Creek	1.39×10^{10}	3.17×10^{12}	(implicit)	$\mathbf{3.19 \times 10^{12}}$
Toms Creek including Little Toms Creek	2.61×10^{10}	2.56×10^{13}	(implicit)	$\mathbf{2.56 \times 10^{13}}$
Little Toms Creek	1.04×10^{10}	8.53×10^{12}	(implicit)	$\mathbf{8.54 \times 10^{12}}$
Crab Orchard Branch	0.0	9.98×10^{12}	(implicit)	$\mathbf{9.98 \times 10^{12}}$

[1] The point source permitted to discharge in the Sepulcher Creek, Toms Creek including Little Toms Creek, Little Toms Creek and Crab Orchard Branch watershed are presented in section 5.2.

7. Allocations

Reduction

The annual average TMDL and *E. coli* load values from section 6.2, together with the waste load allocation from the permitted bacteria sources in section 5.2, were plugged into Table 21 to determine the required reduction. Since the required reduction will only apply to the non-point sources, the LA value was used to calculate the required percent reduction. The full calculations are presented in Appendix C.

Table 21. TMDL and required reduction for Sepulcher Creek, Toms Creek and Crab Orchard Branch

Sepulcher Creek Allowable Loads (cfu/yr.)		**Average Annual EC Load (cfu/yr.)**	**Required Reduction**
Waste Load Allocation (WLA)	1.39×10^{10}		
Load Allocation (LA)	3.17×10^{12}		
MOS	(implicit)		
TMDL (annual average)	$\mathbf{3.19 \times 10^{12}}$	$\mathbf{11.1 \times 10^{12}}$	**71%**
Toms Creek Allowable Loads (cfu/yr.)		**Average Annual EC Load (cfu/yr.)**	**Required Reduction**
Waste Load Allocation (WLA)	2.61×10^{10}		
Load Allocation (LA)	2.56×10^{13}		
MOS	(implicit)		
TMDL (annual average)	$\mathbf{2.56 \times 10^{13}}$	$\mathbf{1.64 \times 10^{14}}$	**84%**
Crab Orchard Branch Allowable Loads (cfu/yr.)		**Average Annual EC Load (cfu/yr.)**	**Required Reduction**
Waste Load Allocation (WLA)	0		
Load Allocation (LA)	9.98×10^{12}		
MOS	(implicit)		
TMDL (annual average)	$\mathbf{9.98 \times 10^{12}}$	$\mathbf{174.0 \times 10^{12}}$	**94%**

As illustrated in Table 20 and 21, the WLA for the Sepulcher Creek, Toms Creek and Crab Orchard Branch watersheds has virtually no effect on the LA reduction calculations. On Toms Creek, the WLA represents less than 0.5% of the TMDL load even considering the growth factor of 5 for each point source. The waste load allocation for Sepulcher Creek represents 2% of the TMDL load even considering the growth factor of 5 for each point source. Since recent Sepulcher Creek bacteria measurements indicate only an 8% violation rate, allowing a growth factor of 5 for the watershed should be achievable. Scenarios where the WLA is 5 times existing loads are illustrated in Tables 30 and 31 in Appendix C.

Margin of Safety

The margin of safety requirement is intended to add a level of safety to account for any inherent uncertainty in the TMDL development process and the data used in the development. A margin of safety (MOS) can be either implicit or explicit. An implicit margin of safety relies on the conservative nature of the assumptions, values, and methods used to calculate a TMDL whereas an explicit margin of safety is a value (typically a percentage) applied at some point during the TMDL calculation.

In this study, an implicit MOS was incorporated through the use of conservative analytical assumptions. These include: (1) the use of the single-most extreme water quality violation event which was used to develop maximum exceedance curve over the entire range of flow conditions, and (2) the computation of average annual load using the average flow conditions. The load duration method of TMDL development has been evaluated against TMDLs that were developed using computer modeling. The results showed the load duration method to be slightly more conservative.

Allocations

In order to apply the reduction calculated above, the average annual *E. coli* load had to be allocated to each of the four non-point sources identified in the BST analysis. Table 13 shows the distribution of the average annual *E. coli* load among sources, the reduction applied to each source, and the allowable loading for each source.

Table 22. Average annual load distribution, reduction, and allowable load by source for each impaired watershed

Sepulcher Creek Watershed

	Total (cfu/yr.)	Human @ 15% (cfu/yr.)	Pet @ 24% (cfu/yr.)	Livestock @ 31% (cfu/yr.)	Wildlife @ 30% (cfu/yr.)
Average Annual Load	1.11×10^{13}	1.64×10^{12}	2.70×10^{12}	3.45×10^{12}	3.30×10^{12}
Reduction	71%	71%	71%	71%	71%
Allowable Annual Load	3.19×10^{12}	0.48×10^{12}	0.78×10^{12}	1.00×10^{12}	0.96×10^{12}

Toms Creek Watershed

	Total (cfu/yr.)	Human @ 17% (cfu/yr.)	Pet @ 17% (cfu/yr.)	Livestock @ 37% (cfu/yr.)	Wildlife @ 30% (cfu/yr.)
Average Annual Load	1.64×10^{14}	2.79×10^{13}	3.72×10^{13}	6.01×10^{13}	4.88×10^{13}
Reduction	84%	84%	84%	84%	84%
Allowable Annual Load	2.62×10^{13}	4.46×10^{12}	4.35×10^{12}	9.62×10^{12}	7.81×10^{12}

Crab Orchard Watershed

	Total (cfu/yr.)	Human @ 27% (cfu/yr.)	Pet @ 21% (cfu/yr.)	Livestock @ 18% (cfu/yr.)	Wildlife @ 34% (cfu/yr.)
Average Annual Load	1.74×10^{14}	4.70×10^{13}	3.65×10^{13}	3.13×10^{13}	5.92×10^{13}
Reduction	94%	94%	94%	94%	94%
Allowable Annual Load	9.98×10^{12}	0.28×10^{13}	0.22×10^{13}	0.19×10^{13}	0.36×10^{13}

7.1. Consideration of Critical Conditions

EPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of Sepulcher Creek, Toms Creek and Crab Orchard Branch is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards. The sources of bacteria for Sepulcher Creek, Toms Creek and Crab Orchard Branch are a mixture of dry and wet weather driven sources. TMDL development using the load-duration approach applies to the full range of flow conditions; therefore, the critical conditions for Sepulcher Creek, Toms Creek and Crab Orchard Branch were addressed during TMDL development.

7.2. Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality because of hydrologic and climatological patterns. The load-duration approach allows the pattern of water quality exceedances to be examined for seasonal variations. The load-duration method used to develop this TMDL implicitly incorporates the seasonal variations of precipitation and runoff by looking at the highest water quality violation and applying it to the entire stream flow record when calculating the TMDL.

8. Implementation and Reasonable Assurance

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the bacteria impairments on the Sepulcher Creek, Toms Creek and Crab Orchard Branch. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan, and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels in the stream. These measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the recent "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.state.va.us/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

8.1. TMDL Implementation Process

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems. In the Guest River, many of these practices are in place thanks to the proactive approach of the Guest River Group and cooperating citizens within the watershed.

In urban areas, reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Other BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

8.2. *Stage I Implementation Goal*

As stated in Section 7.0 the Sepulcher Creek TMDL requires 71%, Toms Creek TMDL requires 84% and Crab Orchard Branch TMDL requires 94% reductions in non-point source loading in order to attain a 0% violation of water quality standards. In order to evaluate interim reduction goals for a phased implementation plan, several reduction levels and their associated violation rates were assessed. Reduction curves similar to the max exceedance/reduction curve of Figure 17 were plotted on the Sepulcher Creek, Toms Creek and Crab Orchard Branch load-duration curves. These reduction curves are presented in Figures 18, 19, and 20.

Figure 18. Load duration curve illustrating the TMDL and reduction curves for Sepulcher Creek at station 6BSEP000.55

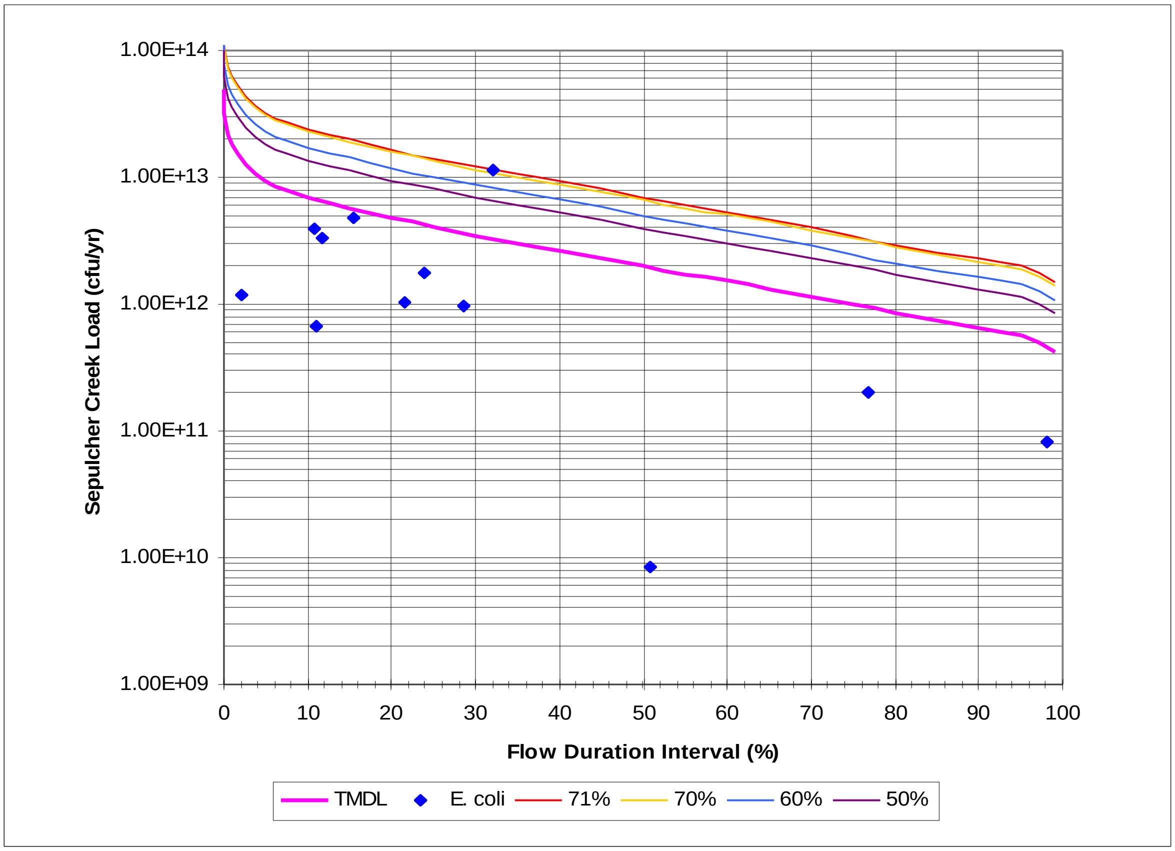


Table 23 shows the theoretical violation rates for the various load reductions on Sepulcher Creek presented in Figure 18.

Table 23. Sepulcher Creek Load Reductions and WQS Violation Rates

Load Reduction	Violation Rate
71%	0%
70%	8%
60%	8%
50%	8%
Current Load	8%

Based on the reduction analysis presented above and a goal of measurable water quality improvement, a suitable Phase I reduction level would be 50%. Table 24 presents the Phase I load allocations based on reduction to 50% of in-stream loads.

Table 24. Sepulcher Creek Phase I Load Allocations (based on a 50% reduction)

	Total (cfu/yr.)	Human (cfu/yr.)	Pet (cfu/yr.)	Livestock (cfu/yr.)	Wildlife (cfu/yr.)
Average Annual Load	1.11×10^{13}	**1.64×10^{12}**	**2.70×10^{12}**	**3.45×10^{12}**	**3.30×10^{12}**
Reduction	50%	98%	95%	72%	0
Target Annual Load	5.55×10^{12}	**4.1×10^{11}**	**7.56×10^{11}**	**1.04×10^{12}**	**3.30×10^{12}**

Figure 19. Load duration curve illustrating the TMDL and reduction curves for Toms Creek at station 6BTMS000.06

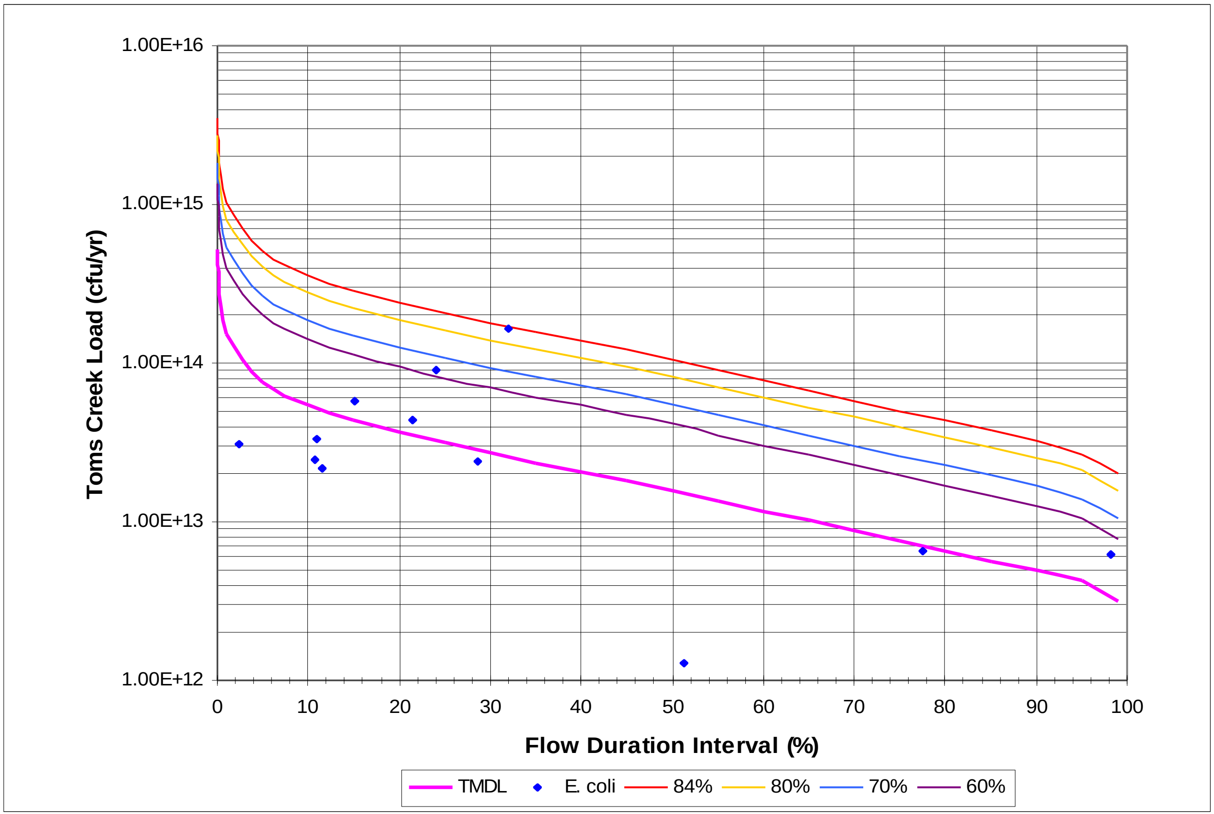


Table 25 shows the theoretical violation rates for the various load reductions on Toms Creek presented in Figure 19.

Table 25. Toms Creek Load Reductions and WQS Violation Rates

Load Reduction	Violation Rate
84%	0%
80%	8%
70%	8%
60%	17%
Current Load	42%

Based on the reduction analysis presented above and a goal of measurable water quality improvement, where less than 10% violation rate was the outcome, a suitable Phase I reduction level would be 70%. Table 26 presents the Phase I load allocations based on a 70% reduction of in-stream loads.

Table 26. Toms Creek Phase I Load Allocations (based on a 70% reduction)

	Total (cfu/yr.)	Human (cfu/yr.)	Pet (cfu/yr.)	Livestock (cfu/yr.)	Wildlife (cfu/yr.)
Average Annual Load	1.64×10^{14}	**2.79×10^{13}**	**2.72×10^{13}**	**6.01×10^{13}**	**4.88×10^{13}**
Reduction	70%	99	99	99	0
Target Annual Load	5.7×10^{13}	**2.79×10^{11}**	**2.72×10^{11}**	**6.01×10^{11}**	**4.88×10^{13}**

Figure 20. Load duration curve illustrating the TMDL and reduction curves for Crab Orchard Branch at station 6BCRA000.31

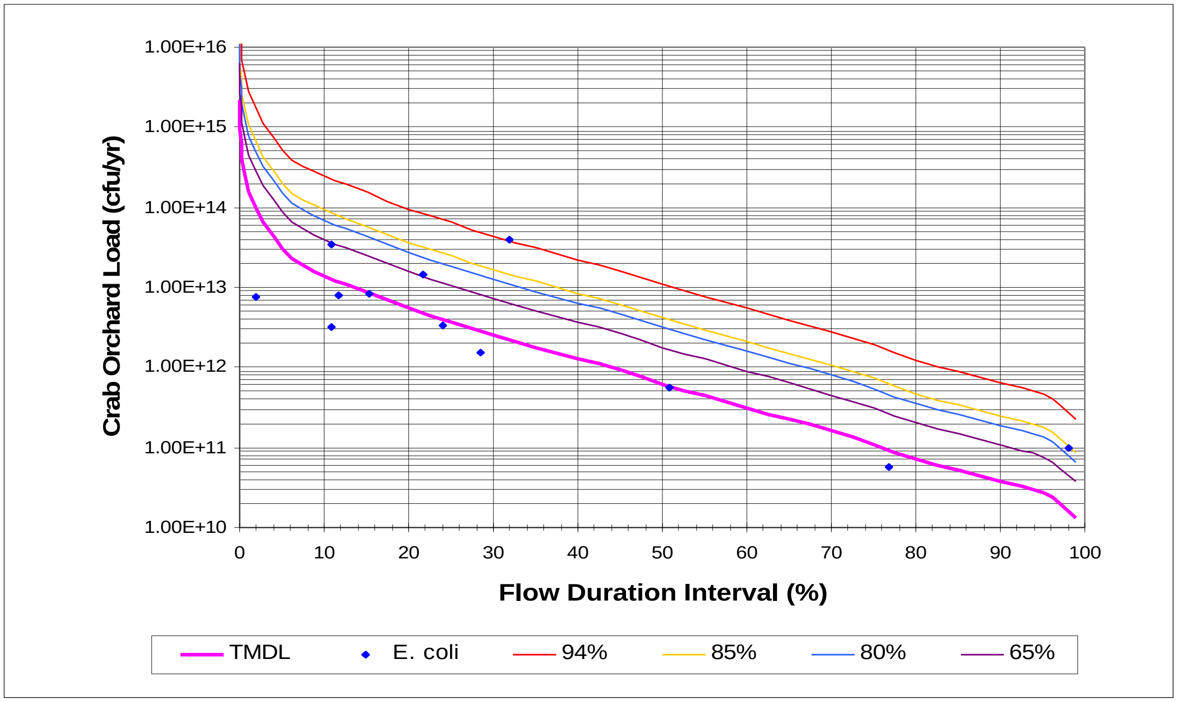


Table 27 shows the theoretical violation rates for the various load reductions on Crab Orchard Branch presented in Figure 20.

Table 27. Crab Orchard Branch Load Reductions and WQS Violation Rates

Load Reduction	Violation Rate
94%	0%
85%	8%
80%	17%
65%	25%
Current Load	33%

Based on the reduction analysis presented above and a goal of measurable water quality improvement with less than 10% violation rate, a suitable Phase I reduction level would be 85%. Table 28 presents the Phase I load allocations based on an 85% reduction of in-stream loads. In order to reduce the violation rate in this watershed to less than 10%, wildlife reductions are also part of this scenario.

Table 28. Crab Orchard Branch Phase I Load Allocations (based on a 85% reduction)

	Total (cfu/yr.)	Human (cfu/yr.)	Pet (cfu/yr.)	Livestock (cfu/yr.)	Wildlife (cfu/yr.)
Average Annual Load	1.74×10^{14}	**4.7×10^{13}**	**3.65×10^{13}**	**3.13×10^{13}**	**5.92×10^{13}**
Reduction	85%	99	99	99	72
Target Annual Load	1.74×10^{13}	**4.7×10^{11}**	**3.65×10^{11}**	**3.13×10^{13}**	**1.66×10^{13}**

It is not the intention of the TMDL to manage wildlife contributions, thus the first step would be to address the human, pet and livestock reductions as completely as possible. An additional management scenario is provided with 65% reduction. With a 65% reduction, the violation rate is 25% and there is no wildlife reduction. Table 29 illustrates the allocation reductions for this management scenario.

Table 29. Crab Orchard Branch Management Scenario Load Allocations (65% reduction)

	Total (cfu/yr.)	Human (cfu/yr.)	Pet (cfu/yr.)	Livestock (cfu/yr.)	Wildlife (cfu/yr.)
Average Annual Load	1.74×10^{14}	**4.7×10^{13}**	**3.65×10^{13}**	**3.13×10^{13}**	**5.92×10^{13}**
Reduction	65%	99	99	99	0
Target Annual Load	6.09×10^{13}	**4.7×10^{11}**	**3.65×10^{11}**	**3.13×10^{11}**	**5.92×10^{13}**

In order to provide some insight into the nature of the Sepulcher Creek, Toms Creek and Crab Orchard Branch water quality violations and to better target possible BMPs, the correlation between violations, stream flow change, and local precipitation was examined.

Results indicate that violations occurred during times of precipitation and increasing stream flow or just after a precipitation event with stable or decreasing stream flow. This suggests that those violations could be related to runoff events. The complete analysis is presented in Appendix D.

BMPs effective in correcting dry weather/low-flow violations of the bacteria water quality standard typically include: streamside fencing for cattle exclusion, straight pipe replacement, and septic system repair. Some of the BMPs effective in reducing bacteria runoff from precipitation events include: riparian buffers zone, retention ponds/basins, range and pasture management, and animal waste management. Detailed lists of BMPs and their relative effectiveness will be determined and presented in the TMDL implementation plan for the Sepulcher Creek, Toms Creek and Crab Orchard Branch watershed.

8.3. Link to Ongoing Restoration Efforts

The local Guest River Group, over the past 5 years, has made significant progress in implementing Best Management Practices (BMP) in the Guest River watershed. Some of those efforts have occurred in Sepulcher Creek, Toms Creek and Crab Orchard Branch watersheds. VDEQ and the Guest River Group believe additional grants monies, through the TMDL program, would be greatly beneficial to reach members of the community that have not yet participated in BMP programs.

8.4. Reasonable Assurance for Implementation

8.4.1. Follow-Up Monitoring

VADEQ will continue to monitor Sepulcher Creek, Toms Creek and Crab Orchard Branch in accordance with its ambient monitoring program. These monitoring station include 6BSEP000.55, 6BTMS000.60, and 6BCRA000.31. VADEQ and VADCR will continue to use data from the monitoring stations on Sepulcher Creek, Toms Creek and Crab Orchard Branch to evaluate reductions in bacteria counts and the effectiveness of the TMDL in attainment of water quality standards. Ambient sampling includes field parameters (temperature, pH, dissolved oxygen, conductivity), bacteria, nutrients and solids. Future bacteria sampling will consist of *E. coli* sampling only, since the interim fecal coliform bacteria criteria no longer applies after twelve *E. coli* samples have been collected.

8.4.2. Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in the 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

8.4.3. Implementation Funding Sources

An essential factor in implementing TMDLs is funding. One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for Virginia's Nonpoint Source Management Program. Watershed restoration activities, such as TMDL implementation, are eligible for Section 319 funding. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation Reserve Enhancement Program (CREP) and Environmental Quality Incentive Programs (EQIP), the Virginia State Revolving Loan Program, and the VA Water Quality Improvement Fund (WQIP). The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

8.4.4. Wildlife Contributions and Water Quality Standards

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards. While managing overpopulation of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

To address this issue, Virginia has proposed (during its recent triennial water quality standards review) a new "secondary contact" category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for "secondary contact recreation" which means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)". These new criteria will become effective pending EPA approval and can be found at http://www.deq.state.va.us/wqs/rule.html.

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of bacterial contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at http://www.deq.state.va.us/wqs/WQS03AUG.pdf

Based on the above, EPA and Virginia have developed a process to address the wildlife issue. First in this process is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of overpopulation's. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in section 8.1 above. DEQ will re-assess water quality in the stream during and after the implementation of the stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, a UAA may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the UAA phase because the water quality standard exceedances attributed to wildlife in the model may have been very small and infrequent and within the margin of error.

9.0 Public Participation

The development of the Sepulcher Creek, Toms Creek and Crab Orchard Branch TMDL would not have been possible without public participation. A public meeting was held in Tacoma, Virginia on October 17, 2002 to discuss the process for TMDL development and the source assessment input. Twenty-seven people attended. Copies of the presentation materials and the draft TMDL report were available for public distribution. The meeting was public noticed in the Virginia Register. There was a 30 day-public comment period and no written comment was received. The final public meeting was held January 26, 2004. Thirty-eight people attended. One written comment was received during the 30-day public comment period.

10. References

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Appendix A

Glossary

GLOSSARY

Note: All entries in italics are taken from USEPA (1998). All non-italicized entries are taken from MapTech (2002).

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. *That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)*

Ambient water quality. *Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

Anthropogenic. *Pertains to the [environmental] influence of human activities.*

Antidegradation Policies. *Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of waterbodies.*

Background levels. *Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.*

Bacteria. *Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.*

Bacterial source tracking (BST). A collection of scientific methods used to track sources of fecal contamination.

Best management practices (BMPs). *Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

Biosolids. Biologically treated solids originating from municipal wastewater treatment plants.

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is section 303(d), which establishes the TMDL program.*

Concentration. *Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

Concentration-based limit. *A limit based on the relative strength of a pollutant in a waste stream, usually expressed in milligrams per liter (mg/L).*

Confluence. The point at which a river and its tributary flow together.

Contamination. *The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.*

Cost-share program. *A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).*

Critical condition. *The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.*

Designated uses. *Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.*

Dilution. *The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

Direct runoff. *Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.*

Discharge. *Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

Discharge permits (under NPDES). *A permit issued by the U.S. EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established* *under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.*

DNA. Deoxyribonucleic acid. The genetic material of cells and some viruses.

Domestic wastewater. *Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.*

Drainage basin. *A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

Effluent. *Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.*

Effluent limitation. *Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.*

Endpoint. *An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).*

Existing use. *Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).*

Fecal Coliform. Indicator organisms (organisms indicating presence of pathogens) associated with the digestive tract.

Feedlot. *A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.*

Geometric mean. A measure of the central tendency of a data set that minimizes the effects of extreme values.

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

Ground water. *The supply of fresh water found beneath the earths surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.*

Hydrograph. *A graph showing variation of stage (depth) or discharge in a stream over a period of time.*

Hydrologic cycle. *The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.*

Hydrology. *The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.*

Indicator. *A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.*

Indicator organism. *An organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.*

In situ. *In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

Isolate. An inbreeding biological population that is isolated from similar populations by physical or other means.

Limits (upper and lower). The lower limit equals the lower quartile – 1.5x(upper quartile – lower quartile), and the upper limit equals the upper quartile + 1.5x(upper quartile – lower quartile). Values outside these limits are referred to as outliers.

Loading, Load, Loading rate. *The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.*

Load allocation (LA). *The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).*

Loading capacity (LC). *The greatest amount of loading a water can receive without violating water quality standards.*

Margin of safety (MOS). *A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the* *receiving waterbody (CWA section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).*

Mathematical model. *A system of mathematical expressions that describe the spatial and temporal distribution of water quality constituents resulting from fluid transport and the one or more individual processes and interactions within some prototype aquatic ecosystem. A mathematical water quality model is used as the basis for waste load allocation evaluations.*

Mean. The sum of the values in a data set divided by the number of values in the data set.
MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

Monitoring. *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

Narrative criteria. *Nonquantitative guidelines that describe the desired water quality goals.*

National Pollutant Discharge Elimination System (NPDES). *The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

Natural waters. *Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.*

Non-point source. *Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.*

Numeric targets. *A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.*

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Peak runoff. *The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

Permit. *An authorization, license, or equivalent control document issued by EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

Phased approach. *Under the phased approach to TMDL development, load allocations and wasteload allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.*

Point source. *Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.*

Pollutant. *Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

Pollution. *Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.*

Privately owned treatment works. *Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.*

Public comment period. *The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a Federal Register notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

Publicly owned treatment works (POTW). *Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.*

Raw sewage. *Untreated municipal sewage.*

Receiving waters. *Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

Restoration. *Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

Riparian areas. *Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.*

Riparian zone. *The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

Runoff. *That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.*

Septic system. *An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.*

Sewer. *A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.*

Slope. *The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

Stakeholder. Any person with a vested interest in the TMDL development.

Standard. In reference to water quality (e.g. 200 cfu/100 ml geometric mean limit).

Storm runoff. *Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

Streamflow. *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

Stream restoration. *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

Surface area. *The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

Surface runoff. *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

Surface water. *All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

Topography. *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

Total Maximum Daily Load (TMDL). *The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

Transport of pollutants (in water). *Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

Tributary. *A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

Variance. A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

DACS. Department of Agriculture and Consumer Services.

DCR. Department of Conservation and Recreation.

DEQ. Virginia Department of Environmental Quality.

VDH. Virginia Department of Health.

Wasteload allocation (WLA). *The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).*

Wastewater. *Usually refers to effluent from a sewage treatment plant. See also* ***Domestic wastewater****.*

Wastewater treatment. *Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

Water quality. *The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

Water quality criteria. *Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

Water quality standard. *Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.*

Watershed. *A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*

WQIA. Water Quality Improvement Act.

Appendix B

Antibiotic Resistance Analysis
(MapTech)

When performing ARA, isolates (colonies picked from membrane filtration plates) of *E. coli* or *Enterococcus* are transferred to a 96-well tissue culture plate (one isolate per well) containing a selective liquid medium. The 96-well plates are incubated and confirmed as *E. coli* or *Enterococcus* by color changes in the liquid after incubation (Figure 1). Antibiotic stock solutions are prepared and each of twentyeight or more antibiotic/concentrations is added separately to flasks of autoclaved and cooled Trypticase Soy Agar (TSA) from the stock solutions to achieve the desired concentration, and then poured into sterile 15x100mm petri dishes.

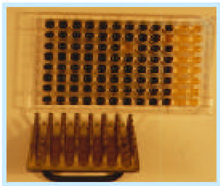


Figure 1. 96-well plate after incubation.

Control plates (no antibiotics) are included with each set. Isolates are transferred from the 96-well plate using a stainless steel 48-prong replica plater (Sigma). The replicator is flame-sterilized (95% ethanol) after inoculation of each TSA plate. Resistance to an antibiotic is determined by comparing each isolate to the growth of that isolate on the control plate. A one (1) is recorded for growth and a zero (0) is recorded for no growth (Figure 2). This is repeated for each isolate on each of the 30 antibiotic plates to develop a profile.

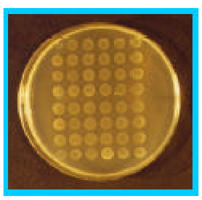


Figure 2. TSA control plate (with no antibiotics) showing growth of all 48 isolates.

The profile is then compared against the known source library to determine the source of the isolate (see data analysis section). The basic process is the same for all approaches, that is, a data base of known sources analyzed using the BST method of choice must be developed and samples of unknown bacterial origin are collected, analyzed and compared to the known source database. For studies, such as Total Maximum Daily Loads (TMDL), we recommend the ARA procedure due to typical cost constraints. Typically we analyze 24 isolates per unknown source (e.g. stream or well water) sample. This provides measurements of the proportion of a given source that are in increments of approximately 4%. If more precision is required, 48 isolates can be analyzed, resulting in resolution of approximately 2%. If the sampling is to be done in a geographical area where a database of known sources has not been developed, we will need to collect samples from known sources (i.e. human, livestock, wildlife) and compare them to our existing databases to determine if one of our existing databases is compatible with the study area. Twenty-four isolates from each of these samples will be analyzed. If no existing database is compatible, we will need to develop a database for the study area. The number of samples needed depend on variability of source samples. We have had a good deal of success in the past by using existing databases through obtaining known source samples from each group (i.e. human, livestock, wildlife) in the study area and comparing them to existing databases.

Appendix C

Calculations

Calculations

Permit Load Calculation from Section 5.2.

Permitted Load cfu/d = Q gal/d * 3.785 l/gal * 1000 ml/l * 126 cfu/100 ml

Where:

126 cfu/100 ml = Geometric Mean *E. coli* standard
Q ft^3/s = Design Flow in gallons per day
cfu = *E. coli* colony forming units.
l = liters
ml = milliliters
gal = gallons

Allowable Load Calculation from Section 6.2.

TMDL cfu/yr = Q ft^3/s * 7.48 gal/ft^3 * 3.785 l/gal * 1000 ml/l * 235 cfu/100 ml * 60 s/min * 60 min/day * 24 hrs/day * 365 days/yr

Where:

TMDL cfu/yr = Allowable load in cfu/yr
235 cfu/100 ml = Instantaneous *E. coli* standard
Q ft^3/s = Flow in cubic feet per second
cfu = *E. coli* colony forming units.
l = liters
ml = milliliters
s = seconds
min = minutes
yr = year
gal = gallons

Required Reduction Calculation from Section 7.

TMDL cfu/yr = LA cfu/yr + WLA cfu/yr + MOS (cfu/yr)

OL = LA cfu/yr + WLA cfu/yr

% reduction = [(OL - TMDL)/OL] * 100

Where:

TMDL = total maximum daily load
LA = load allocation
WLA = waste load allocation
MOS = margin of safety
OL = observed load (average annual load)

Table 30. Future Scenario Average annual *E. coli* loads and TMDL for Sepulcher Creek, Toms Creek and Crab Orchard Branch watershed (cfu/yr.)

	WLA[1]	LA	MOS	TMDL
Sepulcher Creek	6.97×10^{10}	3.12×10^{12}	(implicit)	**3.19×10^{12}**
Toms Creek	1.39×10^{11}	2.55×10^{13}	(implicit)	**2.56×10^{13}**
Crab Orchard Branch	0.0	9.98×10^{12}	(implicit)	**9.98×10^{12}**

[1] The point source permitted to discharge in the Sepulcher Creek, Toms Creek and Crab Orchard Branch watershed are presented in section 5.2. WLA represents 5 times the existing load for each point source which is much less than 1% of TMDL for Toms Creek and 2% of the TMDL for Sepulcher Creek.

Table 31. Future Scenario TMDL and required reduction for Sepulcher Creek, Toms Creek and Crab Orchard Branch

Sepulcher Creek Allowable Loads (cfu/yr.)		Average Annual EC Load (cfu/yr.)	Required Reduction
Waste Load Allocation (WLA)	6.97×10^{10}		
Load Allocation (LA)	3.12×10^{12}		
MOS	(implicit)		
TMDL (annual average)	**3.19×10^{12}**	**11.1×10^{12}**	**71%**
Toms Creek Allowable Loads (cfu/yr.)		**Average Annual EC Load (cfu/yr.)**	**Required Reduction**
Waste Load Allocation (WLA)	1.39×10^{11}		
Load Allocation (LA)	2.55×10^{13}		
MOS	(implicit)		
TMDL (annual average)	**2.56×10^{13}**	**1.64×10^{14}**	**84%**
Crab Orchard Branch Allowable Loads (cfu/yr.)		**Average Annual EC Load (cfu/yr.)**	**Required Reduction**
Waste Load Allocation (WLA)	0		
Load Allocation (LA)	9.98×10^{12}		
MOS	(implicit)		
TMDL (annual average)	**9.98×10^{12}**	**174.0×10^{12}**	**94%**

Appendix D

Flow Change and Precipitation Analysis

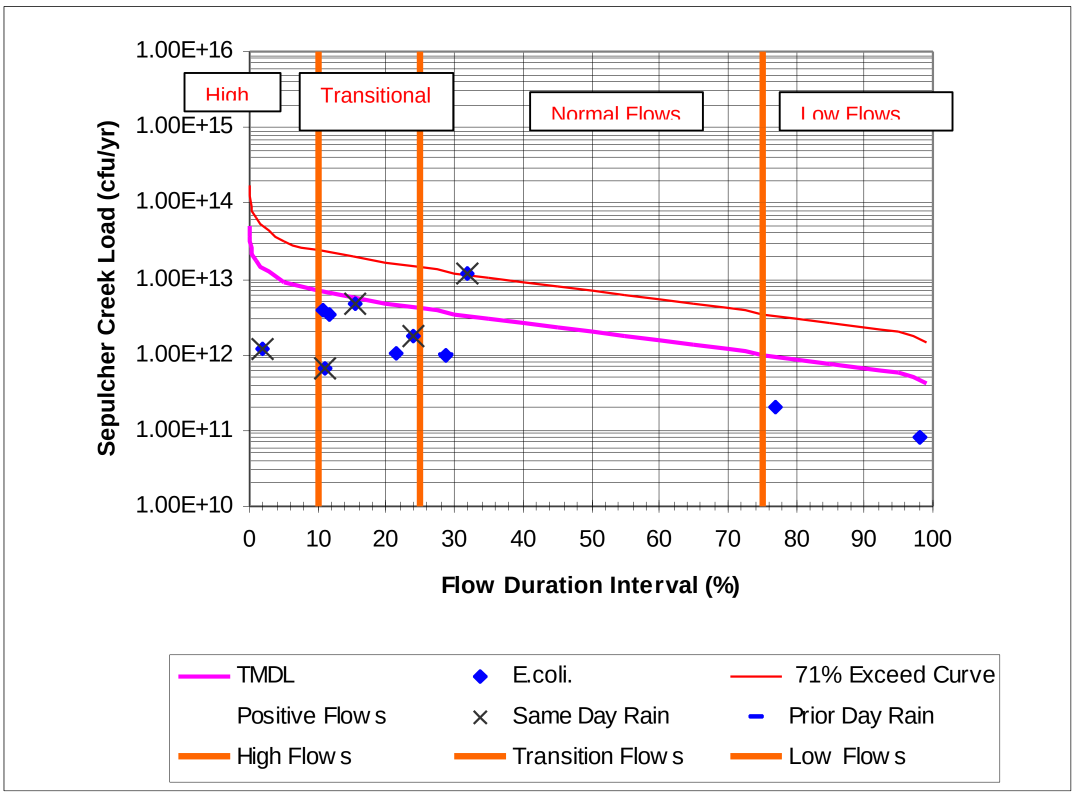
In the interest of better-targeted BMPs, the correlation between water quality violations, stream flow changes and precipitation was investigated. The goal was to determine which violations might be related to runoff and which might be related to direct deposition.

As stated in Section 6.1 on flow data, the continuos stream gauge used to reference flow estimates for each of these streams is located on Clinch River. To assess the link between flow changes and precipitation events, precipitation records from the Wise, VA weather station, located approximately 10 miles northwest of the Sepulcher Creek, Toms Creek and Crab Orchard Branch watershed, were examined. Specifically, rainfall on the day before a sample was collected and rain on the day of a sampling event were evaluated. Precipitation events on these days can tell us if violations of the TMDL were the result of a precipitation event within the preceding 24 hours.

Results of the study are presented graphically and in tabular format below.

Sepulcher Creek

Precipitation and Flow Annotated WQS Violation Events (Sepulcher Creek Watershed)

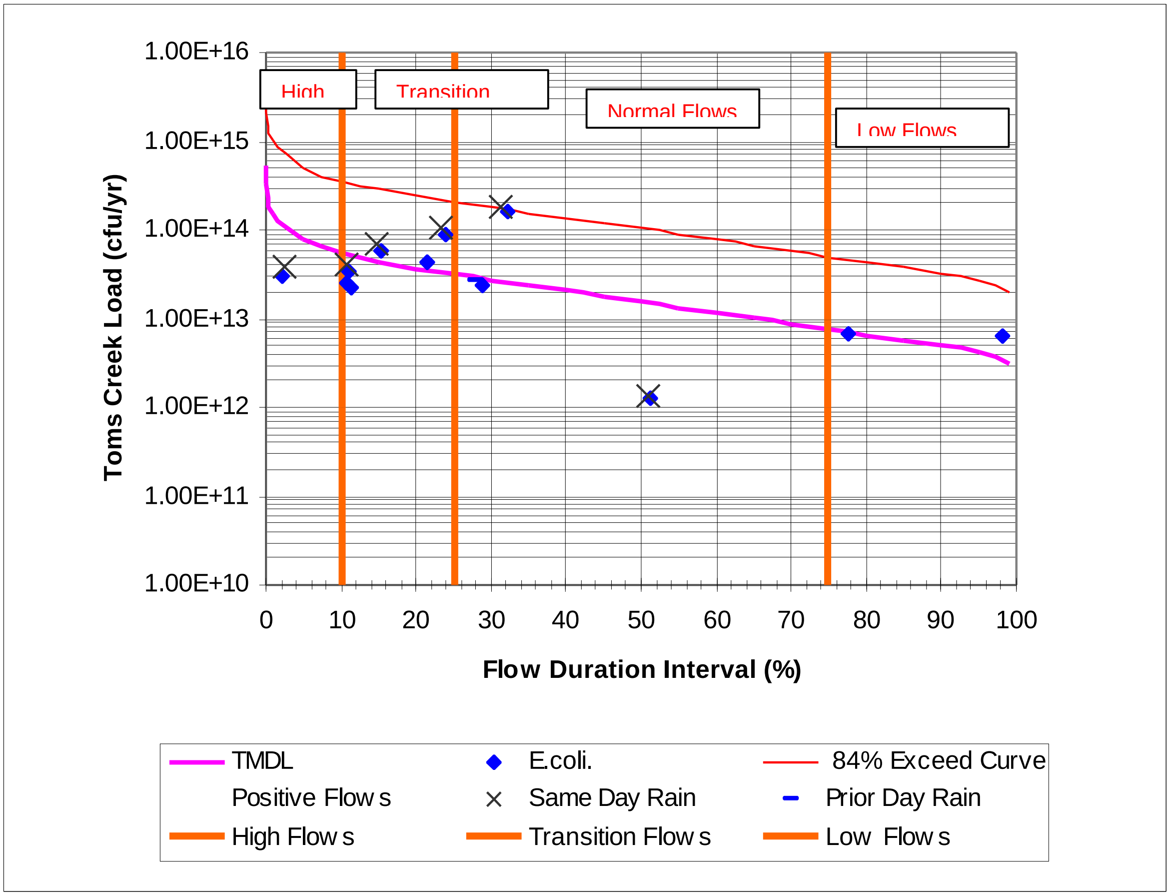


The exceedance is associated with a rainfall event. The results of the study suggest that the violation with precipitation data (8%) could be related to runoff.

Additional information regarding the nature of the violation can be gleaned from looking at the flow conditions under which the violation occurred. It occurred during normal flow, however the flow was decreasing which also suggests runoff conditions.

Toms Creek

Precipitation and Flow Annotated WQS Violation Events (Toms Creek Watershed)

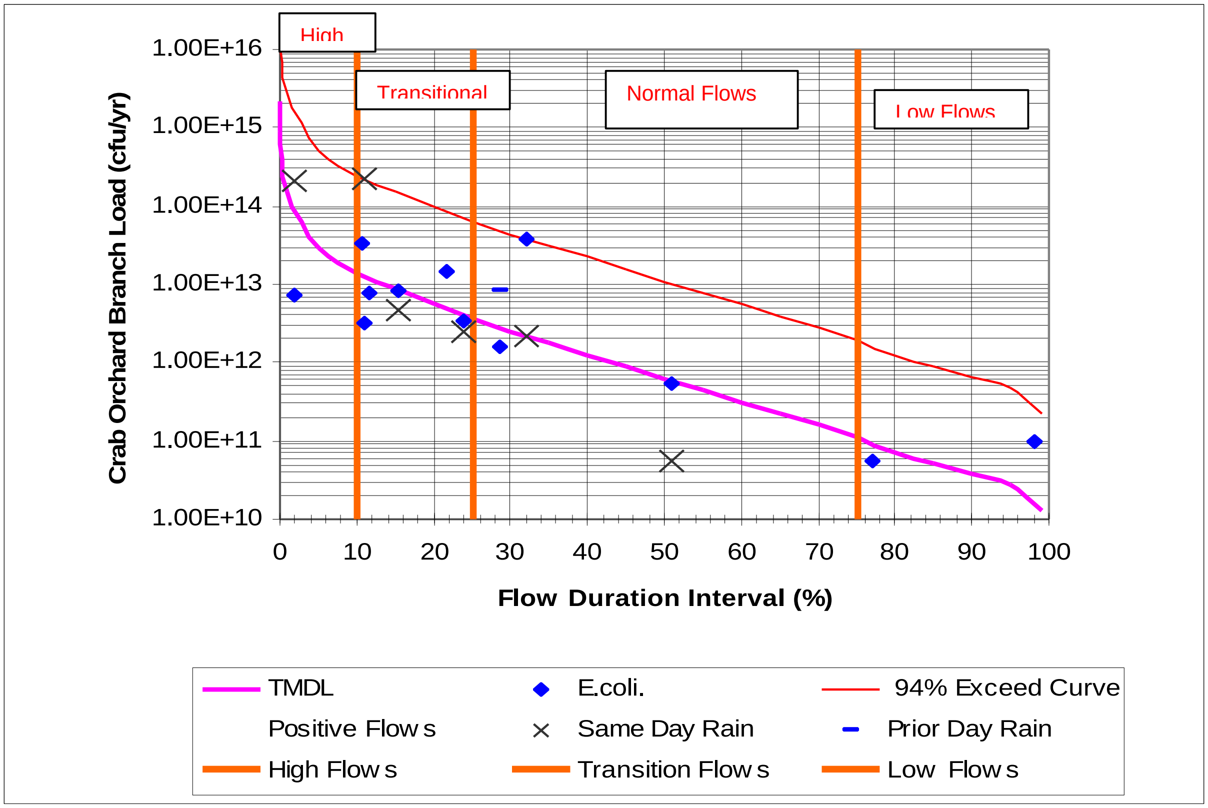


The results of the study suggest that as many as three of the five violations could be related to runoff events. This can be seen in the graph above where those data points above the lower curve had same day rainfall.

Looking at the flow conditions under which the violations occur, three of the exceedances occurred during transitional flows. One exceedance, the violation requiring the highest load reduction, occurred during normal flow. One exceedance occurred in the range of low flows.

Crab Orchard Branch

Precipitation and Flow Annotated WQS Violation Events (Crab Orchard Branch Watershed)



The results of the study suggest that 3 of the 4 violations could be related to runoff events. This can be seen in the graph above where those data points above the lower curve had same day or prior day rainfall.

Looking at the flow conditions under which the violations occur, two of the exceedances occurred during high or transitional flows. One exceedance, the violation requiring the highest load reduction, occurred during this flow regime. One exceedance occurred in the range of low flows.

Water Quality Standard Violations, Stream Flow Change, and Precipitation

Sampling Date	Fecal Coliform (cfu/100 mL)	Measured *E. coli* Value (cfu/100 mL)	Duration Interval	*E. coli* Load (cfu/yr)	Increasing Flow	Same Day Rain (inches)	Prior Day Rain (inches)
Sepulcher Creek Watershed							
09/05/2002	240	40	98	8.17E+10	no	*0*	*0*
10/23/2002	60	50	77	1.99E+11	no	*0*	*0*
11/21/2002	260	100	24	1.77E+12	no	*0.29*	*0*
12/16/2002	440	120	12	3.32E+12	no	0	0
01/27/2003	80	1	51	8.33E+09	no	0.05	0
02/18/2003	280	20	2	1.17E+12	no	0.22	0
03/04/2003	200	140	11	3.99E+12	no	0	0
04/21/2003	430	24	11	6.79E+11	no	0.1	0
05/21/2003	2500	820	32	1.15E+13	yes	0.75	0
06/09/2003	450	200	15	4.77E+12	no	0.21	0
07/14/2003	270	62	29	9.55E+11	no	0	0.05
08/20/2003	210	54	22	1.04E+12	no	0	0
Toms Creek Watershed							
09/05/2002	2000	410	98	4.20E+15	no	*0*	*0*
10/23/2002	1000	220	78	2.10E+15	no	*0*	*0*
11/21/2002	900	660	24	1.89E+15	no	*0.29*	*0*
12/16/2002	360	100	12	7.55E+14	no	0	0
01/27/2003	150	20	51	3.15E+14	no	0.05	0
02/18/2003	490	65	2	1.03E+15	yes	0.22	0
03/04/2003	460	110	11	9.65E+14	no	0	0
04/21/2003	640	150	11	1.34E+15	no	0.1	0
05/21/2003	4000	1500	32	8.39E+15	yes	0.75	0
06/09/2003	2700	310	15	5.67E+15	no	0.21	0
07/14/2003	800	200	29	1.68E+15	no	0	0.05
08/20/2003	3700	290	21	7.76E+15	no	0	0
Crab Orchard Branch							
09/05/2002	8400	1300	98	9.68E+10	no	*0*	*0*
10/23/2002	2000	140	77	5.58E+10	no	*0*	*0*
11/21/2002	2000	150	24	2.53E+12	no	*0.29*	*0*
12/16/2002	650	220	12	1.14E+13	no	0	0
01/27/2003	5000	22	51	5.59E+10	no	0.05	0
02/18/2003	8000	610	2	2.06E+14	no	0.22	0
03/04/2003	770	58	11	3.24E+12	no	0	0
04/21/2003	8000	4100	11	2.26E+14	no	0.1	0
05/21/2003	3200	230	32	2.18E+12	yes	0.75	0
06/09/2003	3600	130	15	4.66E+12	no	0.21	0
07/14/2003	4400	690	29	8.22E+12	no	0	0.05

(cyan)	Positive flow change with same day or prior day precipitation event.
(green)	Negative or stable flow change with prior day precipitation event.
(gray)	*E. Coli* Data (not transformed)